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The American Fern Journal: After 110 Years, a Look Back

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Volume one of the American Fern Journal (AFJ) was published in 1910, and this official journal of the American Fern Society has been publishing the work of fern and lycophyte scientists every one of those subsequent 110 years. In 1960, Ralph C. Benedict, who had been editing the AFJ for its 50 years since its origin, wrote a short article celebrating the journal and discussing how it came to be (Benedict, 1960). The American Fern Society (AFS) was born in 1893 and at that time also launched the "Linnaean Fern Bulletin." Initially, the AFS controlled that publication, but when society membership dwindled, one of the members (Willard N. Clute) worked out an arrangement with his colleagues to take control of its content, management, and distribution, and he also changed the name to "The Fern Bulletin." Clute held sway over The Fern Bulletin as editor for its entire 20-year run, and frequently included his own opinion pieces as well as reports on the "Linnaean Fern Chapter of the Agassiz Association," a predecessor to the AFS. The Fern Bulletin flourished for a number of years, and even began including "The Bryologist, a Department of The Fern Bulletin" in its pages, but contributors dwindled during the first decade of the twentieth century.

In 1910, the AFS members sought to regain control of their official publication and a group of members took on the challenge of making that happen. Negotiations with Mr. Clute to transition The Fern Bulletin to oversight by the AFS failed, and what ultimately became the Executive Council of the AFS assumed publication of a separate journal, which they called the American Fern Journal. In a "Foreword" in volume 1, number 1, it was explained that a strong majority of the AFS members supported having the Society own and publish its official journal. That first issue also included papers on the distribution of *Botrychium* species, the diverse forms of *Polypodium* found in Maine, and a comparison of the structure of ferns and "fern allies," setting the stage for diverse future contributions. Meanwhile, the Fern Bulletin ceased publishing in 1912.

As is clear from the listing of AFJ editors appended here, the journal content has not been controlled by single individuals, and there has never been an "editorial page" that could encourage the expression of particular opinion or policy. In general, the editors have been scientific leaders of their time, with verifiable credentials to oversee the consideration of submitted manuscripts. Until 1972, there was always a set of three to five "editors" who appear to have shared the editorial duties and likely agreed amongst themselves on who would handle which submissions. The change to having a single "editor" supported by a number of "associate editors" was made in 1972 and has been in place ever since. David Lellinger, the first editor using

this system, recalls that this editorial arrangement appeared to be a natural evolution from oversight by a set of co-editors, and occurred as the health of Conrad Morton (who had shouldered much of the editorial management for nearly 20 years) declined. Morton died in 1973, a year after Lellinger became editor-in-chief, with the associate editors vetting manuscripts in subject areas that were new or distant from his expertise. In more recent years, a "managing editor," who helps with transitioning accepted manuscripts into publication, was added.

Over the decades since, the AFJ has broadened its content to match the trends in research on ferns and lycophytes, and the set of associate editors has mirrored these changes in disciplinary emphasis. Journal content has ranged from such topics as chlorophyll and lipid changes during spore germination, to gametophyte development in axenic culture, to chromosome counts and meiotic behavior in hybrids, to depictions of spore morphology, to descriptions of new species and monographs of genera, to biogeography and species distributions, to ecology of gametophytes and sporophytes. Beginning in the 1980s, special issues of the AFJ were devoted to summarizing emerging fields such as biosystematics, population biology, changing views of species concepts, molecular data related to evolutionary studies, lycophyte phylogeny, and the impact of genomics on fern and lycophyte studies. Over the past 110 years, the AFJ has captured and shared the diverse research discoveries of the field, and it will continue to do so long into the future.

Editors of the American Fern Journal, 1910-2020

Volume 1
1910: Ralph Curtis Benedict
1911: Philip Dowell

Volume 2
1912: Philip Dowell

Volumes 3–4
1913–1914: Editor, R. C. Benedict; Managing Editor, E. J. Winslow

Volumes 5–24
1915–1933: Editors, R. C. Benedict, E. J. Winslow, and C. A. Weatherby

Volumes 24–26
1934–1936: Editors, R. C. Benedict, E. J. Winslow, W. R. Maxon, and C. A. Weatherby

Volumes 27–30
1937–1940: Editors, C. A. Weatherby, R. C. Benedict, and W. R. Maxon

Volumes 31–37
1941–1947: Editors, W. R. Maxon, R. C. Benedict, C. V. Morton, and Ira L. Wiggins

Volumes 38–41
1948–1951: Editors, C. V. Morton, R. C. Benedict, and Ira L. Wiggins

Volumes 42–50
1952–1960: Editors, C. V. Morton, R. C. Benedict, Ira L. Wiggins, and A. C. Smith

Volumes 51–55
1961–1965: Editors, Ira L. Wiggins, C. V. Morton, Rolla M. Tryon Jr., and John H. Thomas

Volumes 56–61
1966–1971: Editors, David B. Lellinger, C. V. Morton, Rolla M. Tryon Jr., and Ira L. Wiggins

Volume 62
1972: Editor-in-Chief, David B. Lellinger; Associate Editors, C. V. Morton, Rolla M. Tryon Jr., and Ira L. Wiggins

Volume 63
1973: Editor-in-Chief, David B. Lellinger; Associate Editors, John T. Mickel, and Ira L. Wiggins

Volumes 64–73
1974–1983: Editor-in-Chief, David B. Lellinger; Associate Editors, David W. Bierhorst, Gerald J. Gastony, and John T. Mickel

Volume 74
1984: Editor-in-Chief, David B. Lellinger; Associate Editors, David W. Bierhorst, Gerald J. Gastony, John T. Mickel, and Terry R. Webster

Volumes 75–79
1985–1989: Editor, Alan R. Smith; Associate Editors, Gerald J. Gastony, Christopher Haufler, David B. Lellinger, and Terry R. Webster

Volume 80
1990: Editors, Carol and James Peck; Associate Editors, Gerald J. Gastony, Christopher Haufler, David B. Lellinger, and Michael I. Cousens

Volumes 81–84
1991–1994: Editor, James H. Peck; Associate Editors, Gerald J. Gastony, Christopher H. Haufler, David B. Lellinger, and Robbin C. Moran

Volumes 85–88
1995–1998: Editor, George Yatskievych; Associate Editors, Gerald J. Gastony, Christopher H. Haufler, Robbin C. Moran, and James H. Peck

Volumes 89–92
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Volumes 93–96
2003–2006: Editor, R. James Hickey; Associate Editors, Gerald J. Gastony, Gary K. Greer, Christopher H. Haufler, Robbin C. Moran, and James H. Peck

Volume 97
2007: Editor, Jennifer M. O. Geiger; Managing Editor, Jill Anne Dill; Associate Editors, Gerald J. Gastony, Gary K. Greer, Christopher H. Haufler, R. James Hickey, and Robbin C. Moran

Volumes 98–100
2008–2010: Editor, Jennifer M. O. Geiger; Managing Editor, Jill Anne Dill; Associate Editors, Gerald J. Gastony, Gary K. Greer, Christopher H. Haufler, R. James Hickey, Robbin C. Moran, and James E. Watkins Jr.

Volume 101
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Volume 102
2012: Editor, Jennifer M. O. Geiger; Managing Editor, Jill Anne Dill; Associate Editors, Nan Crystal Arens, José María Gabriel y Galán, Gerald J. Gastony, Gary K. Greer, Christopher H. Haufler, R. James Hickey, Paolo Labiak, Robbin C. Moran, Nathalie Nagalingum, Carl Rothfels, Emily Sessa, Michael Sundue, and James E. Watkins Jr.

Volume 103
2013: Editor, Warren D. Hauk; Associate Editors, Nan Crystal Arens, José María Gabriel y. Galán, Gerald J. Gastony, Gary K. Greer, Christopher H. Haufler, R. James Hickey, Klaus Mehltreter, Paolo Labiak, Robbin C. Moran, Carl Rothfels, Emily Sessa, Michael Sundue, and James E. Watkins Jr.

Volume 104–105
2014–2015: Editor, Warren D. Hauk; Managing Editor, Tom A. Ranker; Associate Editors, Nan Crystal Arens, José María Gabriel y Galán, Gerald J. Gastony, Gary K. Greer, Christopher H. Haufler, R. James Hickey, Klaus Mehltreter, Paolo Labiak, Robbin C. Moran, Nathalie Nagalingum, Carl Rothfels, Emily B. Sessa, Michael Sundue, and James E. Watkins Jr.

Volumes 106–107
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Volume 108–110
2018–2020: Editor, Christopher H. Haufler; Managing Editor, Tom A. Ranker; Associate Editors, Joshua P. Der, José María Gabriel y Galán, Gary K. Greer,

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Volume 111

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Literature Cited

Benedict, R. C. 1960. The genesis of the American Fern Journal. American Fern Journal 50: 2–5.

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Ferns and Lycophytes of Gori Valley, Western Himalaya, Uttarakhand: A Case Study

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Abstract.—This study was carried out in the Gori Valley catchment of Uttarakhand, Western Himalaya, to document more fully the distribution and ecology of ferns and lycophytes at a montane site divided into 7 elevation sampling zones from 1,800–4,000 m (subtemperate to alpine) across a distance of approximately 30 km. A total of 16 families, 33 genera, and 92 species were found. Species richness, total species density ha^{-1}, diversity, and Pielou's species evenness per elevation zone (m) were calculated for each zone. The data were used to evaluate three hypotheses addressing changes in density and species distribution in relation to the biogeographic and climatic conditions across the seven elevation sampling zones. Total density of ferns and lycophytes tended to decrease from Zone 1 toward Zone 7; although Zones 1-3 (sub-temperate) had clearly higher mean densities than those in Zones 5-7 (alpine). The highest density was found in Zone 1 (Lilam 1,800 m) and lowest density was found in Zone 6 (Burfu 3,450 m). After finding a significant difference among all mean densities for each elevation zone ($p < 0.001$), using a non-parametric Welch's ANOVA, a Games-Howell test for pairwise comparisons of the means showed that each of the mean densities for species in Zones 1 to 3 was significantly different from each of the species densities in Zones 5 to 7 ($p < 0.05$). The mean densities for Zone 4 were not significantly different from any of the other zonal mean densities (*i.e.*, 1–3 and 5–7), suggesting that Zone 4 is a transitional zone between two end member Zones (1–3 and 5–7).

Key Words.—Elevation zones, montane ecosystems, species density, species diversity, species evenness

A substantial amount of research has been published on fern and lycophyte floras in forested areas across elevation gradients in a global perspective (*e.g.*, Kessler *et al.*, 2001, 2011; Moran and Smith, 2001); and at particular geographic locales (Karger *et al.*, 2011). Studies in neotropical regions include investigations of fern species richness and distribution along elevation gradients in Costa Rica (Kluge and Kessler 2011; Kluge, Kessler, and Dunn,

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2006; Watkins *et al.,* 2006), and an analysis of the relationships of species richness with productivity at regional and local scales in Ecuador (Kessler *et al.,* 2014). Salazar *et al.* (2015) examined the diversity patterns of ferns along an elevation gradient in Andean tropical forests. They used plot-based elevation fern species richness surveys compiled from recent field work, and additional evidence from their own published research at locations between 18° N and 18° S along the Andean mountain range. Their analyses included comparisons of the transects of patterns of species richness and composition, and distribution of taxa. Khine *et al.* (2017) published the first plot-based inventory of vascular plant species' elevation distribution in northern and northwestern Myanmar at elevation gradients. Four 400-m^2 plots were sampled at intervals of 200 m in natural or little-disturbed forests and alpine thickets. Using 3,978 specimens, a total of 299 species from 72 genera and 24 families were identified. An interesting study by Hernández *et al.* (2018) examined the richness patterns of ferns along an elevation gradient in the Sierra de Juárez in Oaxaca, Mexico and compared it with data published from studies in Central and South America. They report that there is a decline in species richness towards the subtropics and temperate regions, and this appears to be rather abrupt within Central America.

Asian montane locales are particularly rich in fern assemblages, and several studies across a broad geographic range have examined the richness and diversity of ferns and lycophytes in diverse locations. Tanaka and Sato (2013) conducted field surveys to evaluate the elevation belts, boundary, and richness patterns of ferns and lycophytes in the temperate region of central Japan. They found clear elevation boundaries of fern assemblages at 900 and 1,800 m and three fern elevation zones, which corresponded well to the elevation limits of forest types in central Japan. Bhattarai, Vetaas, and Grytnes (2004) explored fern species richness patterns along a central Himalayan elevation gradient and evaluated factors influencing their spatial distribution. They found a unimodal relationship between species richness and elevation, with maximum species richness at 2,000 m. Moreover, they concluded that fern richness had a unimodal response along the energy gradients; however there was a linear response with moisture gradients.

Sureshkumar, Ayyanar, and Silambarasan (2019) studied the species richness of ferns and lycophytes along elevation gradients in Kolli Hills, Eastern Ghats of Southern India along 13 elevation gradients (1,300 to 1,400 m). Ninety-eight species of ferns and lycophytes, 58 genera and 32 families were recorded. The distribution of species richness with elevation on scrub and semi-evergreen forests was unimodal; whereas, species richness in deciduous and evergreen forests showed a monotonic linear distribution. The high diversity of fern and lycophyte species in Kolli Hills was attributed to its richness in various habitats, resulting from an extended altitudinal range and a healthy evergreen forest with a constant increase in rainfall in higher elevations. The diversity and distribution of 68 species of ferns and lycophytes along different ecological gradients (600 to above 1,000 m) in the Satara district of Western India were studied by Patil *et al.* (2016),

including categorization of the species in relation to biogeographic and climatic variables, such as diversity and distribution along elevation ranges, requirements for rainfall, humidity, and temperature. Shukla and Chakravarty (2012) surveyed fern diversity and biomass at the Chilapatta reserve forest of West Bengal Terai Duars in the sub-humid tropical foothills of Indian Eastern Himalayas. They recorded 19 fern species in 9 genera, and 8 families. Highest and lowest frequencies recorded were 25.44 and 0.19; while relative frequency varied from 3.16 to 12.25. Fern density ranged from 93 to 13,403 individuals ha^{-1}. Most of the species were widely distributed in this forested site.

Although there has been recent progress in research on ferns and lycophytes in relation to elevation in India, less is known about the geographic distribution and diversity of these plants in the Western Himalayas (*e.g.*, Punetha, 1989). Clarke (1880), while working exclusively on ferns and lycophytes of northwest Himalaya, utilized samples in the herbarium prepared by Col. R. Strachey for assistance in identifications. Hope (1899–1904) explored many parts of western Himalaya and described some new species. Khullar (2000) published an illustrated fern flora of the West Himalaya and documented 16 families and 164 species. One of the most promising regions for exploration is Uttarakhand in northeastern India, especially the Gori River Valley (Fig. 1). The first scientific information on ferns of Gori Valley (up to Lilam) was in the form of a list prepared by Col. R. Strachey for Atkinson's Gazetteer of north-western provinces (Atkinson, 1882). He enumerated approximately 22 ferns from Gori Valley. Although the richness of the flora in Uttarakhand contributes significantly to the vegetation of Western Himalaya (*e.g.*, Dhar, Rawal, and Samant, 1997; Jalal, Rawat, and Pangtey, 2010), further research is needed to more fully document the richness and diversity of the flora in this biogeographic locale. The geographic, climatic, and vegetation characteristics of this unique region (varying from subtemperate to alpine with increasing elevation) have been concisely reported by Jalal (2012), who also points out the significance of better documenting and conserving the flora of Uttarakhand and the surrounding region.

In this study, we present data on fern and lycophyte diversity, density, species richness, and evenness from seven elevation zones (1,800–4,000 m) from Lilam to Martoli of the Gori Valley over a geographic range of approximately 30 km (Fig. 1).

In addition to documenting the fern and lycophyte flora along this elevation gradient, we evaluated three hypotheses:

1. Fern and lycophyte species are expected to vary significantly, decreasing in densities across increasingly higher elevations among the seven sampling zones of the Gori Valley.
2. Given the broad range of geographic sampling sites along the elevation gradient in the Gori Valley, distribution of fern and lycophyte species is

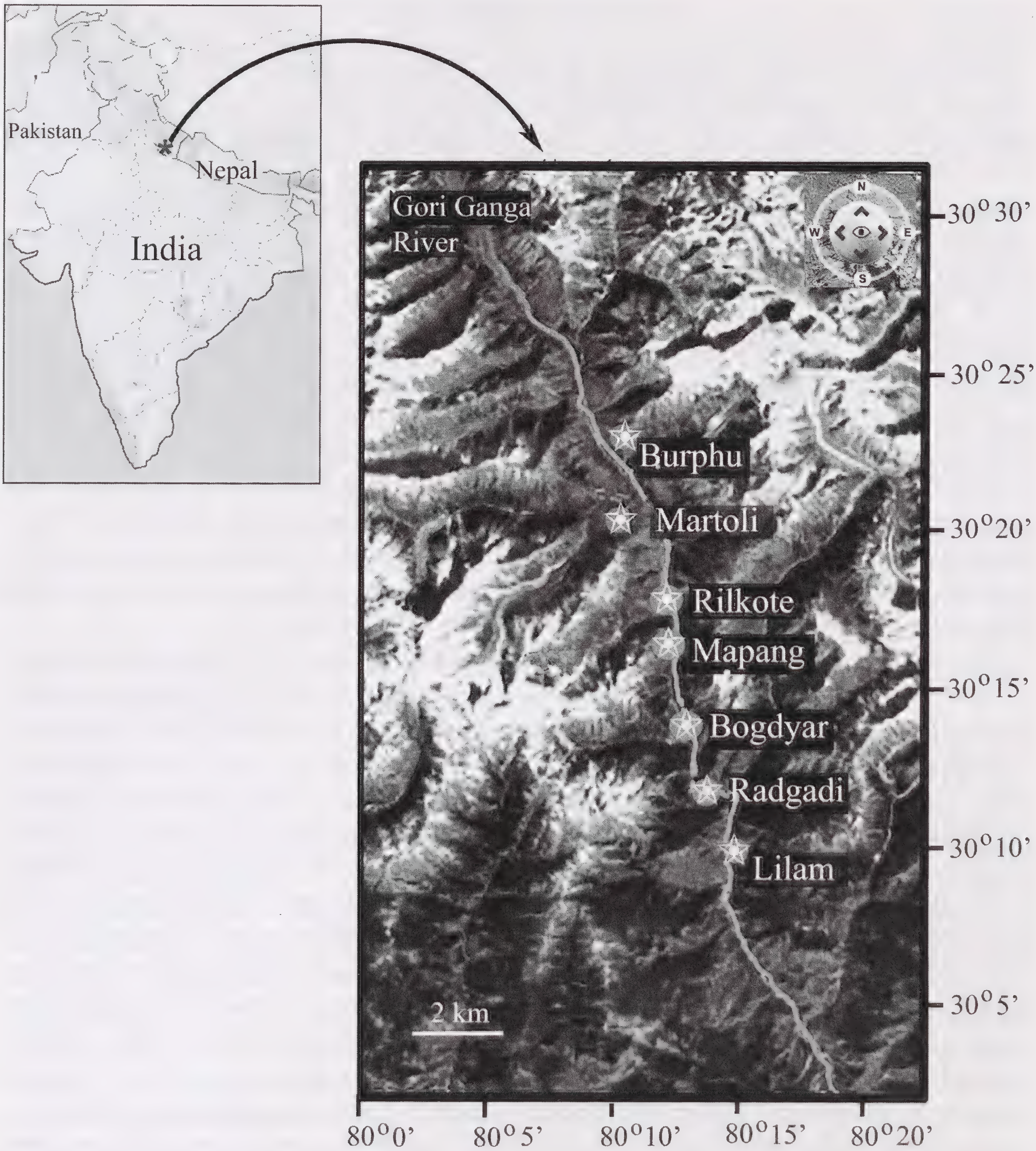

FIG. 1. Locations and geographic coordinates of the seven sampling sites in the Gori River Valley of Uttarakhand, India. Lilam (30° 09′ 40″ N, 80° 15′ 14″ E), Radgadi (30° 10′ 46″N, 80° 13′ 50″ E), Bogdyar (30° 13′ 12″ N, 80° 13′ 20″ E), Mapang (30° 16′ 22″ N, 80° 12′ 46″ E), Rilkote (30° 17′ 26″ N, 80° 13′ 12″ E), Martoli (30° 20′ 50″ N, 80° 11′ 30″ E), and Burphu (30° 22′ 38″ N, 80° 10′ 51″ E). Basemap adapted from *Google Earth*.

expected to be largely localized, with few species occurring in multiple sampling zones.

3. The number of dominant species ($\geq$ 5% of total in the zone), characterizing each sampling zone, will occur largely within that zone, and not be distributed widely across the seven elevation sampling zones.

Materials and Methods

Geographic setting.—Samples of ferns and lycophytes were collected at seven sites at increasing elevation along the Gori River Valley (Fig. 1). The geographic coordinates for each site are reported in the legend of Fig. 1. The Gori Valley is located in the state of Uttarakhand (28° 53′ 24″ to 31° 27′ 50″ N latitudes and 77° 34′ 27″ to 81° 02′ 22″ E longitudes) and extends approximately northwest to southeast within the western Himalaya mountain range. The state of Uttarakhand accounts for approximately 1.62 % of the Indian continent, and occupies an area of 53,483 km^2. The soil (described by Raychaudhri *et al.,* 1963 and Wadia, 1945) when mixed with litter becomes fertile, and has relatively high water holding capacity, which provides highly conducive substrata for a large number of forest floor ferns. Seven major forest types occur in the state (Champion and Seth, 1968): 1. Tropical moist deciduous forest, 2. Subtropical pine forest, 3. Subtropical dry evergreen forest, 4. West Himalayan temperate broad-leaf forest, 5. West Himalayan conifer forest, 6. Subalpine forest, and 7. Alpine scrub. In the present study, the elevation zones ranged from sub-temperate, broad-leaf forests to alpine scrub, with scattered stands of conifers.

The state of Uttarakhand includes some of the richest and most diverse flora of the continent, and contains six National Parks and six Wildlife Sanctuaries (including the exceptional Nanda Devi Biosphere Reserve). The climate of Uttarakhand is strongly influenced by the south-west monsoon, and there are mainly three seasons: pre-monsoon, monsoon, and post-monsoon. Highest precipitation (300 – 400 mm) occurs during the summer monsoon in some locales. Climate in Uttarakhand ranges from subtropical in the southern foothills, averaging summer temperatures of about 30° C and winter temperatures of approximately 18° C. Warm temperate conditions prevail in the Middle Himalayan valleys, with summer temperatures usually hovering about 25° C and cooler winters. Cool temperate conditions dominate the higher areas of the Middle Himalayas, where the summer temperatures are usually around 15 to 18° C and in winter can drop below the freezing point. At higher elevations (3,000 to 3,500 m) the climate is subalpine, and above 3,500 m it is categorized as alpine with cool summers and cold winters – temperatures drop below freezing with accumulations of snow. However, there is considerable variability within these ranges due to the mountain terrain. In the temperate zone of the study site (1,200-2,400 m) the common forests are Banj-Oak (*Quercus leucotrichophora* A. Camus) including broad-leaved and conifer species (*e.g.*, *Acacia catechu* (lf.) Willd., *Ficus benghalensis* L., and *Cupressus torulosa* D. Don).

With respect to the Gori Valley sampling sites, the climate of Lilam is subtemperate; and the geography is characterized by scattered stands of forested areas with abundant flora of ferns, lycophytes, and flowering plants. Some commonly occurring ferns at an elevation of 1,800–2,400 m, collected from Lilam and Radgadi, formed small patches on the forest floor. Mean temperatures in summer range near 20 to 30° C with cooler temperatures in

winter ranging from 15 to 25° C. With increasing elevation along the Gori Valley, the climate becomes increasingly temperate and eventually subalpine to alpine, giving way to a landscape that is largely open vegetation with scattered shrubs and herbaceous plants; but also sparse stands of pine trees, especially on mountain slopes. The Burphu and Martoli sampling sites, at the highest elevations, range from subalpine to alpine.

Sampling.—The study was carried out at seven elevation zones during an expedition (2007–2009) in Gori Valley of India (Fig. 1) from Lilam to Martoli, for at a total distance of approximately 30 km, at the following geographic locations: 1,800 m (Lilam), 2,000 m (Radgadi), 2,700–3,000 m (Bogdyar), 3,100 m (Mapang), 3,350 m (Rilkote), 3,450 m (Burphu), and 4,000 m (Martoli). The ferns and lycophytes from the area were collected mainly in the autumn (September-October) when the weather was most favorable, and fern and lycophyte growth, supported by the summer monsoon rains, was particularly well developed. Within each of the seven sampling zones, quadrats of 10 m x 10 m (100 m^2) were established at ten sites parallel to the Gori River at five locations on each side of the river. The sample sites were selected on the basis that they were representative of the vegetation at the geographic locale, and where there was a good diversity of ferns and lycophytes. Thus, a total of 70 quadrats were used across the seven geographic sampling zones. The average distance between zones along the Gori Valley tract was 1.7 km.

Only terrestrial ferns and lycophytes growing in the soil were collected and recorded within each of the sampling zones. At least two specimens of every species were mounted on a standard herbarium sheet. The specimens were deposited in the Herbarium of Pteridology, Department of Botany, Government Post Graduate College, Pithoragarh. Specimens were taxonomically identified by comparing them with specimens collected by previous workers (available in the Pteridology Laboratory) and with the help of available classical and recent literature (Beddome, 1883,1892; Ching, 1978; Clarke, 1880; Duthie, 1906; Hope, 1899-1904; Khullar, 1994, 2000; Kramer, 1990; Nayar; 1974; Pandey and Pandey, 2003; Pichi Sermolli,1977; Smith *et al.,* 2008). In addition to these works, papers on taxonomy and enumeration of ferns and lycophytes of the area were also consulted (*e.g.*, Alston, 1945; Bir, 1962; Dhir, 1980; Fraser-Jenkins, 1984; Punetha and Kaur, 1987). As far as possible, nomenclature as accepted by Khullar (1994, 2000), Fraser-Jenkins (1997, 2008), Kato and Tsutsumi (2008), and Tsutsumi *et al.* (2016) was followed.

Advice was also given in the identification of specimens by the scientists of the National Botanical Research Institute (CSIR–NBRI), Lucknow; and Botanical Survey of India (B.S.I.), Dehra Dun. In a few cases, only the genus could be definitively identified; in such cases, the sample was identified by the genus name followed by sp.

Analytical procedures.—The taxonomic identifications, number of individuals of each species and community composition of ferns and lycophytes were recorded using conventional methods (Misra, 1968; Raunkiaer, 1934) by enumerating the number of species in ten quadrats of 10 m x 10 m (Yusuf, Tan, and Turner, 2003a, b) at each geographic sampling

zone, and converting the counts to densities (number ha^{-1}) by scaling up the data from the ten quadrats to the estimated densities per hectare (10,000 m^2).

Statistical analyses.—Species richness (S) was calculated by summing up all of the species identified within a given elevation zone. Alpha diversity was defined as the Shannon-Weaver index (H). Where $H = -\sum (p_i * \ln p_i)$; and p_i is the proportion of individuals collected for species (i) relative to the total number of individuals collected for all species; and ln is the natural log. The maximum value of H = 1.0. The evenness of the species (J') was calculated using Pielou's index as follows: $J' = H/H'_{max}$; where H is the Shannon-Weaver index, and H'_{max} is the maximum possible H value for a given set of species that were collected at a sampling site, and is defined as $H'_{max} = \ln S$, where S is the total number of different species identified in the collection at the sampling site. J' varies between zero and 1. Whittaker's coefficient was used for beta diversity (Tuomisto, 2010): $\beta = \gamma/\alpha$, where γ is the Shannon Weaver diversity index for the total species data across the entire seven geographic sampling sites, representing landscape levels of diversity; and α is the site-specific diversity for each of the 7 geographic sampling zones as reported for the Shannon diversity value (H). Because the density data within each of the seven zones was not normally distributed as required for parametric statistical tests, nor sufficiently linear in relation to increasing elevation to use a linear regression model, a nonparametric Welch ANOVA (Excel welchanova-7.xls) was used to statistically examine the mean differences among species densities across the seven elevation zones (1–7). Moreover, as shown in the Results (Fig. 2), there was clear evidence that the mean densities in Zones 1 to 3 were substantially larger than those in Zones 5 to 7, suggesting that application of ANOVA was a suitable statistical method to detect significant mean differences for this particular set of data collected along a tract of the Gori Valley region. Differences between pairs of means, following a significant ANOVA, were tested using the non-parametric Games-Howell test. The level of significance was set at $p \leq 0.05$.

Results

Species densities, and alpha diversity: Evidence for Hypothesis one.—Documentation of fern and lycophyte taxa at each of the seven elevation zones (1,800 m to 4,000 m) are presented for the following measures: (1) Species richness (S), Total species density ha^{-1} (D_T), Diversity (H) and Species evenness (J') per elevation (m) (Table 1); (2) Density (number ha^{-1}) for each genus tabulated by elevation zones (1–7) (Table 2); and (3) Density of fern and lycophyte species reported for each elevation zone (1–7) (Tables A1 – A7). The highest species richness (S), number of species, was found in two zones: S = 25 (Zone 3, Bogdyar 2,700-3,100 m) and S = 26 (Zone 7, Martoli 4,000 m). The lowest number of species (14) was found in Zone 4 (Mapang 3,100 m) (Table 1). All totaled, 16 families, 33 genera, and 92 species were recorded.

Total density of ferns and lycophytes (D_T) tended to decrease from Zone 1 to Zone 7 (Table 1), consistent with Hypothesis 1; as further corroborated for

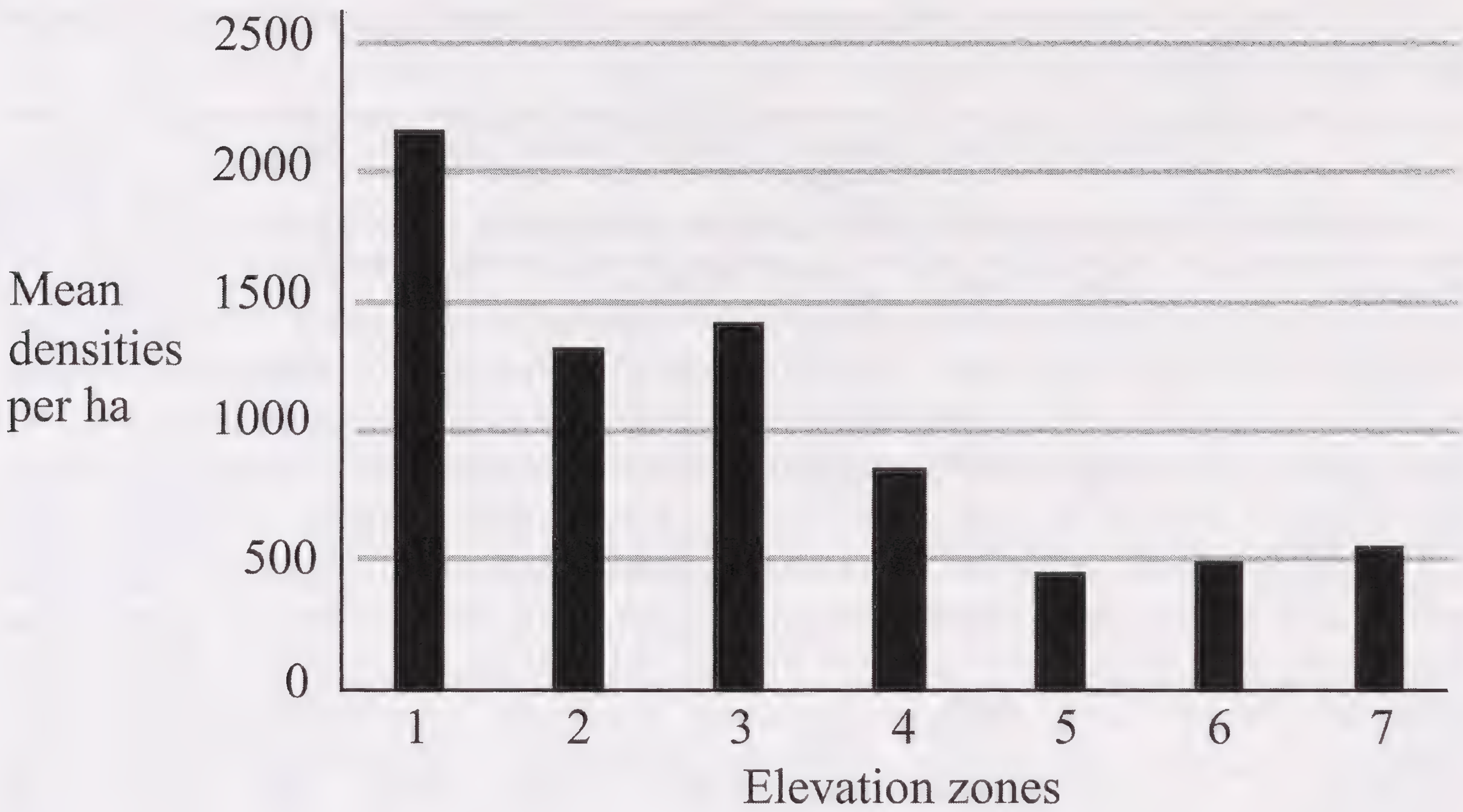

FIG. 2. Mean densities of pteridophyte species plotted in relation to Zones 1 through 7, with Zone 4 possibly as a transitional zone between Zones 1–3 and 5–7, as explained more fully in the text. Holmes-Games comparison of mean differences showed mean densities in Zones 1 to 3 were significantly different from means in Zones 5 to 7 ($p < 0.05$), but mean densities in Zone 4 were not significantly different from any of the other means for Zones 1–3 or 5–7.

mean species densities reported below in the bottom row of Table 2. However, the other measures in Table 1 (species richness, diversity, and species evenness) appeared to have no regular pattern of relationships with increasing elevation. The highest total species density was found in Zone 1 (Lilam 1,800 m) and lowest density was found in Zone 6 (Burphu 3,450 m). However, Zones 2 and 3 were second highest in species density, in addition to having some of the highest species richness values (24 and 25, respectively). Zones 2 and 3 also had the highest diversity (3.26 and 3.17, respectively), as well as the highest species evenness (0.95 and 0.98, respectively).

The densities for each genus found in Zones 1 to 7, including the mean species densities for each zone, are presented in Table 2. The genera with highest total densities (> 10,000 ha^{-1}) include: *Lepisorus* (19,290), *Adiantum*

TABLE 1. Species richness (S), total species density ha^{-1} (D_T), diversity (H) and species evenness (J') per elevation zone (m).

Zone	Elevation	S	D_T	H	J'
1	1,800	20	47,600	1.26	0.39
2	2,000	24	33,360	3.26	0.95
3	2,700-3,000	25	36,980	3.17	0.98
4	3,100	14	12,030	2.04	0.76
5	3,350	21	9,750	2.52	0.82
6	3,450	16	7,920	2.15	0.77
7	4,000	26	14,130	2.86	0.88

TABLE 2. Densities (number ha^{-1}) for genera in Zones 1 to 7, percent of total for each genus and mean species densities.

Genera	Zone 1 1,800 m	Zone 2 2,000 m	Zone 3 2,700-3,000 m	Zone 4 3,100 m	Zone 5 3,350 m	Zone 6 3,450 m	Zone 7 4,000 m	Row totals	Percent of total
Adiantum	6,460	3,890	4,070	80				14,500	8.55
Asplenium	2,810		5,100					7,910	4.67
Athyrium	940		4,010	1,540	1,480	1,450	1,090	10,510	6.20
Botrychium		660	1,370				90	2,120	1.25
Cheilanthes	1,020	1,790	970	410	180	260		4,710	2.78
Christella	1,150		1,850					3,000	1.77
Coniogramme		1,720		150				1,870	1.10
Cryptogramma				420			340	760	0.45
Cyrtomium	690	900						1,590	0.94
Cystopteris					580	830	860	2,190	1.29
Davallodes		1,690						1,690	1.00
Deparia		2,950	1,340	160	1,400	850	1,310	8,010	4.72
Dryopteris		1,860	3,310	1,200	510	900	500	8,280	4.88
Emodiopteris		2,170						2,170	1.28
Equisetum						3,160	3,080	6,240	3.68
Gymnopteris	1,160							1,160	0.68
Hypodematium	710							710	0.42
Lepisorus	9,960	4,770		1,220	1,280		2,060	19,290	11.38
Microsorum	1,160							1,160	0.68
Onychium	730		540	3,430				4,700	2.77
Osmunda				3,420	3,580		1,410	8,410	4.96
Paradavallodes		3,260	6,150		620		690	10,720	6.32
Pellaea							210	210	0.12
Phegopteris							480	480	0.28
Polystichum		6,300	3,290		540		910	11,040	6.51
Pseudophegopteris			1,720					1,720	1.01
Pteridium			2,020					2,020	1.19
Pteris	550	1,920	3,020					5,490	3.24
Pyrrosia	9,840	2,490						12,330	7.27
Selaginella	11,110							11,110	6.55
Tectaria	860							860	0.51
Woodsia		1,350					50	1,400	0.83
Woodwardia		1,200						1,200	0.71
Mean sp. densities	**2,380**	**1,390**	**1,479**	**859**	**464**	**495**	**550**		

(14,500), *Pyrrosia* (12,330), *Polystichum* (11,040), *Athyrium* (10,510), and *Selaginella* (11,110). The lowest densities recorded (< 1,000 ha^{-1}) were: *Cryptogramma* (760), *Hypodematium* (710), *Pellaea* (210), *Phegopteris* (480), and *Tectaria* (860).

The mean species densities recorded for each of the seven sampling zones across the elevation gradient (reported in the final row of Table 2) are presented as a bar graph (Fig. 2). In addition to the approximate negative slope of the bar graph across the seven sampling sites, a visual inspection of the graph suggests that the mean density data for Zones 1 to 3 is substantially larger than for Zones 5 to 7. The results of a Welch ANOVA test showed there

was a statistically significant difference among the seven mean densities ($F_s = 12.4$, df = 6, N = 124, $p < 0.001$). The Games-Howell test for pairwise comparisons of the means indicated that each of the mean densities for species in Zones 1 to 3 was statistically significant from each of the species densities in Zones 5 to 7 ($p < 0.05$). The mean density for Zone 4 was not significantly different from any of the other zonal mean densities (*i.e.*, 1–3 and 5–7), suggesting that Zone 4 is a transitional zone between the two groups of end member Zones (1–3 and 5–7). That is, Zone 4 may be a transitional zone between two biogeographic zonal regions (Zones 1–3 and Zones 5–7). The statistically significant ANOVA result, and data on total density (D_T) presented above, further support Hypothesis 1; *i.e.*, fern and lycophyte species are expected to vary significantly, decreasing in densities from those in Zones 1-3 to those in Zones 5-7 at increasingly higher elevations among the seven sampling zones of the Gori Valley. Along the elevation tract, climate varies from sub-temperate with relatively moderate winters (6 to 10° C) and mild summers (15 to 20° C) to scrub alpine, where the winters are substantially more cold and arid (5 to -10° C) and cool to cold summer temperatures (10 to 20° C).

Species distribution, beta diversity and evidence for Hypothesis two.—In addition to the α diversity data presented in Table 1, a Whittaker β diversity coefficient was calculated to determine diversity of fern and lycophyte species among the seven elevational sampling zones, yielding a value of $\beta = 1.67$. To display more fully how the species composition varied among the seven sampling sites, the number of individual species that occurred in only one sampling zone, or alternatively in two, three, four, or five sampling zones is presented as a bar graph in Fig. 3. Sixty-five percent of the total documented species occurred in only one sampling zone and an additional 26 percent occurred in two sampling zones. Very few species occurred in three, four, or five sampling zones; *i.e.*, 6, 1, and 2 %, respectively. These data support Hypothesis 2; namely: Given the broad range of geographic sampling sites along the elevation gradient in the Gori Valley, the distribution of fern and lycophyte species is expected to be largely localized in one zone, with few species occurring in multiple sampling zones.

Patterns of species dominance and evidence for Hypothesis three.—To address Hypothesis 3, and more fully display the pattern of fern and lycophyte species dominance across the seven elevation zones (1–7), the density of each species present in an elevation zone, including the percent of total for each species in each of the seven zones, are presented in Tables A1 to A7 (Appendix). These tables include the mean species density for all species in each zone. Within each table of the Appendix, the species are listed in decreasing order from those with the highest percentage of the total density to those with the lowest percentage of total.

Thirty species all totaled in Tables A1 to A7 were designated as dominant; *i.e.*, they had densities $\geq 5\%$ of the total species that were listed in the zone. Overall, the percentage of dominant species ($\geq 5\%$) that occurred in only one sampling zone, and no other, was 77%. This provides support for Hypothesis 3: The number of dominant species will occur largely within a zone, and are

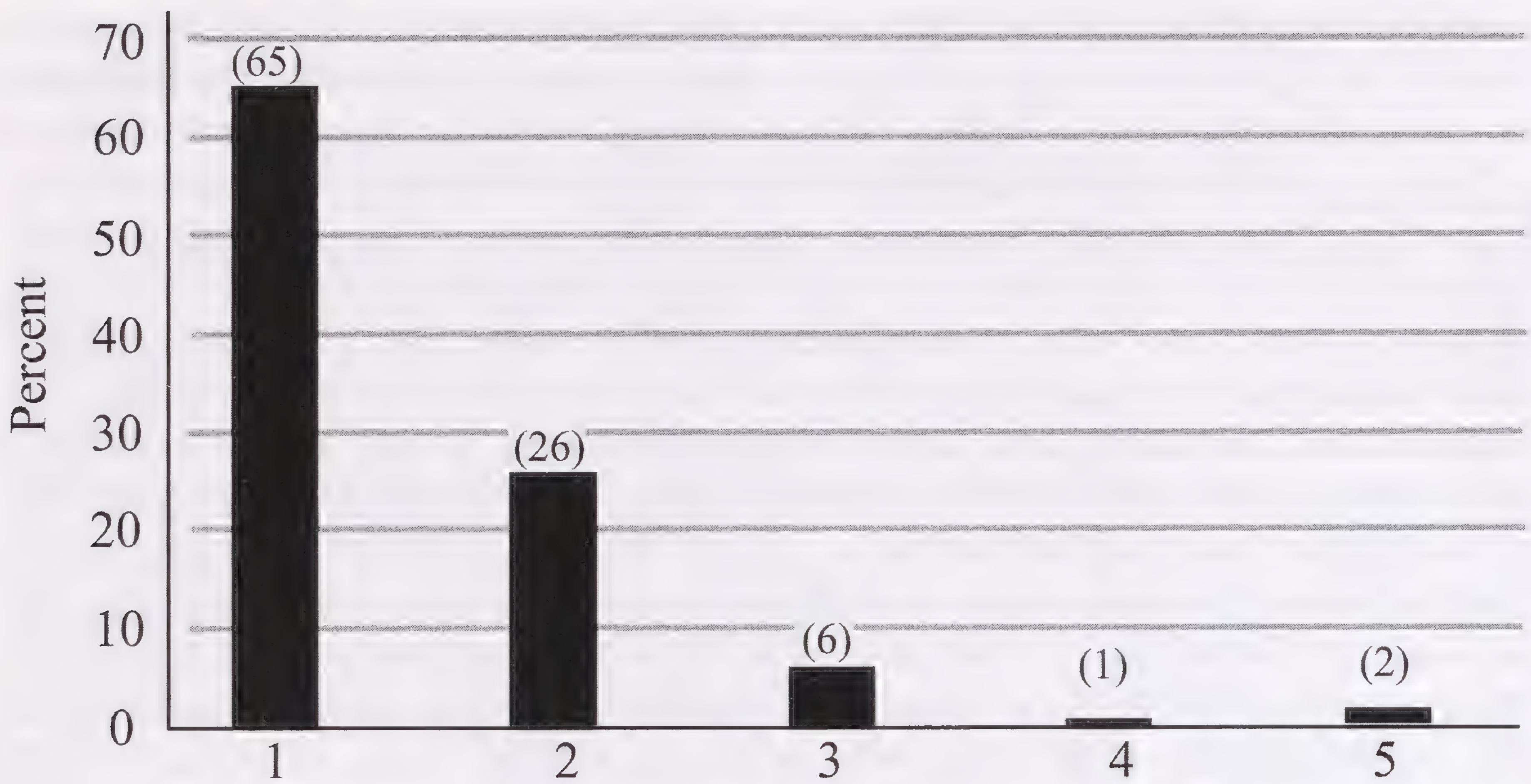

FIG. 3. Plot of the distribution of the percentage of total species enumerated in the seven zones (ordinate) that occurred in only one sampling zone, or occurred in two, three, four, or five sampling zones (abscissa) across the elevational gradient from the lowest elevation (Lilam) to the highest (Martoli). For example, among all of the species enumerated in the seven zones, 65% occurred in only one particular zone of the seven studied; whereas, at the other extreme, only 1% were distributed across four different zones, and 2% were distributed across five zones. Thus, most species were specifically located in either one or two zones within the set of seven zones, indicating that many species in Zones 1 to 7 are limited in their distribution and not widely distributed across the sampling zones.

not distributed widely across the seven geographic sampling zones. That is, the dominant fern and lycophyte species within a zone tend to be specific to, and likely characteristic of, that sampling region, and are not widely distributed among the seven sampling zones along the sampling range of the Gori Valley. Moreover, the percentage of the dominant species that occurred in only two zones was 93%, and most of these species were in two adjacent sampling zones. This suggests that the assemblage of dominant species within localized sampling zones may be a good marker for the fern community found in that biogeographic region. Particularly, given the changing climatic and biogeographic features across each of the seven sampling zones (progressing from subtemperate to scrub alpine), the dominant species in each zone may be a good indicator of the climatic and vegetation assemblages in each of these zones. However, further research is needed to more clearly verify which assemblage of species, if any, is most characteristic of each of the seven sampling zones in the Gori Valley.

The percentage of species that are in the top two most dominant species, among all that are listed within a zone, tends to increase with increasing elevation zone. For example, the two top, dominant species (> 5%) that occur in Zones 1 to 3 (Tables A1 to A3) are in the range of 15 to 25%. In contrast, those in Zones 4 to 7 (Tables A4 to A7) are higher, in some cases as much as 42 to 56%. The top two to three species that are most dominant in each of the

seven zones based on density are: Zone 1 (*Pyrrosia mollis, Selaginella chrysocaulos, Selaginella subdiaphana*), Zone 2 (*Adiantum venustum, Pyrrosia flocculosa, Lepisorus nudus*), Zone 3 (*Adiantum venustum, Asplenium laciniatum*), Zone 4 (*Onychium cryptogrammoides, Osmunda claytoniana, Athyrium schimperi*), Zone 5 (*Osmunda claytoniana, Lepisorus morrisonensis, Cystopteris fragilis*), Zone 6 (*Equisetum arvense, Cystopteris fragilis, Dryopteris redactopinnata*), and Zone 7 (*Equisetum arvense, Osmunda claytoniana, Lepisorus nudus*). As noted above, in Zone 3 there are only two relatively clear top dominance species based on density; *i.e.*, *Adiantum venustum* (11%) and *Asplenium laciniatum* (*c.* 7%). With increasing elevation, the species tend to be representative of more cold-adapted species.

Discussion

A substantial amount of research has been conducted on higher plants in the Himalayan region, including extensive documentation of medicinal plants, especially their ecology, and conservation status (*e.g.*, Benniamin, 2011; Butola and Badola, 2008; Gaur and Bhatt, 1994; Singh, Gopichand, and Todaria, 2015; Upreti *et al.*, 2009). However, with the exception of relevant publications cited in the Introduction, ferns and lycophytes in some regions of the Himalayas have not received such intensive attention. The Gori Valley provides an excellent geographic region to document more fully fern and lycophyte diversity and ecology due to its unique location (biogeographically and in relation to public services) and its rich growth of ferns and lycophytes, many yet to be fully explored. Moreover, the broad range of climatic zones for this study site (1,800 m to 4,000 m) encompassed a wide range of habitats, varying from forested regions in the south (Lilam, Radgadi, and Bogdyar) to an increasingly more arid, colder, and open landscape (Rilkote, Burphu, and Martoli) with largely shrubs and forbs. The latter three zones, overall, are less conducive to supporting rich and diverse fern growth. This study provides some of the first evidence of fern and lycophyte diversity, density, species richness, and their evenness across these seven elevation zones of the Gori Valley in relation to the edaphic and climatic conditions prevailing at each zone.

This study is distinctive compared to other studies in montane regions as reviewed in the Introduction because of the location in a Himalayan river valley within a sampling tract of *c.* 10 km across the seven sampling zones at elevations from 1,800 to 4,000 m. Three hypotheses with predictions related to expectations of changing fern and lycophyte species density and taxonomic composition were evaluated. Given the broad differences in the climate conditions from Zone 1 to Zone 7, Hypothesis 1 predicted fern and lycophyte species would vary significantly, decreasing in densities across increasing elevations among the seven sampling zones of the Gori Valley. This hypothesis was supported by evidence of decreasing total fern and lycophyte densities, and stepwise decreases in mean densities (ANOVA, $p < 0.05$), across the seven zones, with highest densities in the subtemperate zone of Lilam and lowest in

the cold temperate to alpine zones of Burphu and Martoli. Based on the post-hoc analysis of the data (Fig. 2), three zonal regions were identified: Southern region (Zones 1 to 3), a transition region (Zone 4), and a northern region (Zones 5 to 7) that were significantly different from one another.

More particularly, the larger mean densities in Zones 1 to 3 compared to much lower mean densities in Zones 5 to 7 can be attributed to the biogeographic and climatic differences of these two sets of zones. There are distinct differences in the vegetation and annual climate of these two sets of zones (1 to 3 and 5 to 7) in the Gori Valley, which may explain why the two sets of data are statistically different in densities. The sampling locations in Zones 1 to 3 (Lilam, Radgadi, and Bogdyar) are located biogeographically in a sub-temperate climate with substantial stands of broad-leaved trees that provide favorable habitats for growth of ferns and lycophytes. With moderate temperatures during summer and cool to cold weather during winter and favorable annual precipitation, these three zones represent similar biogeographic regimes that support relatively high densities of ferns and lycophytes. By comparison Zones 5 to 7 (Rilkote, Martoli, and Burphu) are increasingly alpine, particularly Martoli and Burphu at the highest elevations, where scrub-alpine vegetation is most common, and patches of trees are largely conifers. Summers are cool or even cold and winters are much more harsh than in Zones 1 to 3. Consequently, with less forest cover and favorable protective vegetation, there is substantially less density of ferns and lycophytes in Zones 5 to 7. Many of the ferns and lycophytes are cold-adapted species. Hence, Zones 5 to 7 constitute a higher elevation, biogeographic regime that stands in sharp contrast to the more moderate biogeographic regime of the lower elevation biogeographic regimes of Zones 1 to 3. Mapang (Zone 4) is at a transitional location along the Gori Valley tract and has intermediate biogeographic and climatic conditions compared to the end-member group of zones (Zones 1 to 3 and Zones 5 to 7). This is reflected in the statistical analyses showing that the end-member groups of zones (Zones 1-3 and 5-7) are significantly different in mean densities from one another, but they are not different statistically from the intermediate Zone 4.

While there tend to be localized differences in mean densities of ferns and lycophytes between Zones 1 to 3 and Zones 5 to 7, beta diversity tends to be high with 65% of the total species occurring in only one of the seven zones (*i.e.*, not widely distributed among the zones), indicating a stronger gradient in species distribution than reflected in the mean densities. This is further evidenced by the changing species composition across the seven zones as presented in Tables A1 to A7, from more moderate climate-adapted species to those tolerant of colder regimes.

Because the species recorded in this study have a wide climate range across subtemperate, temperate, and alpine habitats, the ferns and lycophytes in the southern region (Zones 1 to 3) included species that are typically found in subtropical to temperate regions. *Pteris*, for example, occurring in Zones 1 to 3, is a genus that is generally found in tropical and subtropical regions, but some are temperate (Tryon, Tryon, and Kramer, 1990). *Pteris* spp. are usually

distributed at lower elevations, below 2,500 m in montane locations (Chao *et al.*, 2014). Ferns and lycophytes in the transition region (Zone 4) shared some genera with Zones 1 to 3, including *Adiantum,* as well as *Athyrium*, but with much lower density. Some of these extended into the northern region (Zones 5 to 7) with declining densities. Species of *Cheilanthes*, *Onychium,* and *Deparia,* that first appeared in Zone 2, extended into Zone 4 and to some extent in more northerly zones, but with diminishing numbers. *Osmunda claytoniana*, first recorded in Zone 4, continued in Zones 5 and 7, and is typically found in temperate and colder regions of eastern Eurasia and North America (Kato, 2007). Genera with highest densities in the northern region (Zones 5 to 7) include *Equisetum*, (especially in Zones 6 and 7) and *Phegopteris connectilis* (Zone 7). These are widely distributed species in temperate Asia, Europe, and North America, and *Pellaea nitidula* (also in Zone 7), which has been categorized as a high altitude fern in the Himalayas (Singh, Garkoti, and Pande, 2013). *Woodsia alpina* and *W. lanosa*, known to be more cold adapted, occurred in Zone 7, but with relatively limited densities. *Asplenium viride*, and *A. trichomanes*, in Zone 6, have also been found associated with *W. alpina.* They co-occur sparsely at elevations of 1,100 to 2,600 m in European mountains (*e.g.*, Piekos-Mirkowa and Delimat, 2002). *Polystichum duthei* and *P. nepalense* were found particularly in Zone 7. *Polystichum duthei*, moreover, has been recorded in Kumaon (Himalayas) at elevations of 3,960 to 5,180 m (Christ, 1910).

Evidence, related to Hypotheses 2 and 3, indicates that overall, the fern and lycophyte species collected across this geographic, elevation range in Gori Valley tend to be largely restricted to one or only a few of the zones, with the exception of *Lepisorus nudus*, that was observed in five of the zones from Zone 1 to Zone 7. This species has been reported in the Himalayas as widely distributed and tolerant of colder temperatures below 18° C (Patil *et al.*, 2016). Further research is needed to document these observations more fully and provide more detailed analyses of assemblages of species across this wide geographic range.

More generally, previous studies at different geographical locales have documented some of the distributional patterns that ferns typically exhibit with increasing elevation in mountainous regions. For example, Young and Leon (1991) described the diversity, distribution, and ecology of 174 species in 43 genera of ferns and lycophytes in Rio Abiseo National Park, north-central Peru. The most diverse ecological zone was the montane rain forest zone located from 3,100 m upwards to timberline, which contained 109 fern and lycophyte species. They suggested the reasons for this were a high and constant humidity, the abundance of some species, and the sharing of species with both of the adjacent zones. Bhattarai, Vetaas, and Grytnes (2004) confirmed the importance of moisture on fern distributions, as the peak coincides spatially with climatic factors that enhance moisture levels, the maximum number of rainy days, and the cloud zone. However, they observed a maximum species richness at 2000 m, which is in line with results from the Neotropics (Salazar *et al.*, 2015). A list of 342 montane fern and lycophyte

species of Central America, occurring at elevations higher than 2,500 m, was presented by Mehltreter (1995). His report focused on their geographical and elevation distribution in Costa Rica, Central America. The elevation distribution for Costa Rica shows the highest number of species and families at 2,600 to 3,000 m, and the strongest decline of species was at 3,000 to 3,400 m, representing the timber-line. However, other research at locations in Costa Rica (Kluge, Kessler, and Dunn, 2006, Watkins *et al.,* 2006) indicate a species richness peak at mid-elevations (*c.* 1,700 m).

Although all of these studies are at montane locales, as was our study, comparisons with our evidence must be made with caution because these other studies were done at very different global locations, and in most cases within one montane location, not across a substantial range in biogeographic and climatic regimes, as was the case in our study. However, it is of interest that Mehltreter's data are comparable to ours at least in Zones 2 and 3 (2,000 to 3,000 m elevation), where the species richness, total densities, and especially diversity indices, are among the highest relative to other elevation zones that we documented.

While current evidence of the abundance and diversity of ferns and lycophytes and their ecology at different global locations of similar geographic profile is beginning to show comparable explanations of edaphic and local climatic effects on their distribution and species composition, it is clear that not all montane ecosystems are of equivalent local climatic or biotic characteristics. Therefore, the encouraging current research, within this distinctive tract of elevations within the Gori River Valley, should provide a good platform to examine, more particularly, differences and similarities of fern and lycophyte community composition and ecology across broad global biogeographic locales.

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Literature Cited

Alston, A. G. H. 1945. An enumeration of the Indian species of *Selaginella.* Proceedings of the Indian National Science Academy, Part B 11:211–235.

Atkinson, E. T. 1882. *Gazetteer of the North Western Provinces and Oudh, Vol. X, Himalayan Districts.* Government Printing Office, Allahabad.

Beddome, R. H. 1883. *Handbook to the ferns of British India, Ceylon and the Malay Peninsula.* Thacker, Spink, and Company, Calcutta.

Beddome, R. H. 1892. *Handbook to the ferns of British India, Ceylon and the Malay Peninsula: With Supplement.* Thacker, Spink, and Company, Calcutta.

Benniamin, A. 2011. Medicinal ferns of North Eastern India with special reference to Arunachal Pradesh. Indian Journal of Traditional Knowledge 10:516–522.

Bhattarai, K., O. R. Vetaas, and J. A. Grytnes. 2004. Fern species richness along a central Himalayan elevational gradient, Nepal. Journal of Biogeography 31:389–400.

Bir, S. S. 1962. Some new and little known members of genus *Athyrium* from the Himalayas. Nova Hedwigia 4:165–170.

Butola, J. and K. Badola. 2008. Threatened Himalayan medicinal plants and their conservation in Himachal Pradesh. Journal of Tropical Medicinal Plants 9:125–142.

Champion H. G., and S. K. Seth. 1968. *A revised survey of forest types of India.* Delhi: Government of India.

Chao, Y.-S., G. Rouhan, V. B. Amoroso, and W.-L. Chiou. 2014. Molecular phylogeny and biogeography of the fern genus *Pteris* (Pteridaceae). Annals of Botany 114:109–124; doi:10.1093/aob/mcu086

Ching, R. C. 1978. The Chinese fern families and genera: systematic arrangement and historical origin. Acta Phytotaxinomica Sinica 16:1–19.

Christ, H. 1910. *Die Geographie der Farne.* Gustav Fischer: Jena.

Clarke, C. B. 1880. A review of the ferns of northern India. Transactions of the Linnaean Society of London II Botany 1:425–611 (Reprinted in Delhi, 1973).

Dhar, U., R. S. Rawal, and S. S. Samant. 1997. Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: Implications for conservation. Biodiversity and Conservation 6:1045–1062.

Dhir, K. K. 1980. Ferns of North-Western Himalayas. Bibliotheca Pteridologica 1:1–138.

Duthie, J. F. 1906. *Catalogue of the Plants of Kumaon and of the Adjacent Portions of Garhwal and Tibet, based on the collections made by Strachey and Winterbottom during the years 1846 to 1849 and on the Catalogue originally prepared in 1852 by Sir Richard Strachey.* Lovell Reeve & Co., Limited, London.

Fraser-Jenkins, C. R. 1997. *New species syndrome in Indian pteridology and the ferns of Nepal.* International book distributing Co., Lucknow, India.

Fraser-Jenkins, C. R. 1984. An introduction to fern genera of the Indian subcontinent. Bulletin of the British Museum of Natural History (Bot.) 12:37–76.

Fraser-Jenkins, C. R. 2008. *Taxonomic revision of three hundred Indian subcontinental pteridophytes: with a revised census list; a new picture of fern-taxonomy and nomenclature in the Indian subcontinent.* Bishen Singh Mahendra Pal Singh, Uttarakhand, India.

Gaur, R. D. and B. P. Bhatt. 1994. Folk utilization of some pteridophytes of Deoprayag area in Garhwal Himalaya: India. Economic Botany 48:146–151.

Hernández-Rojas, A., T. Krömer, C. I. Carvajal-Hernández, M. Kessler, A. Weigand, and J. Kluge. 2018. Richness patterns of ferns along an elevational gradient in Sierra de Juarez, Oaxaca, Mexico: a comparison with Central and South America. American Fern Journal 108:76–94.

Hope, C. W. 1899–1904. Ferns of north-western India. Journal of the Bombay Natural History Society 12:527–538, 621–633; 13:25–36, 236–251, 443–461, 657–671; 14:119–127, 252–266, 458–480, 720–749; 15:67–111, 415–429.

Jalal, J. S. 2012. Distribution pattern of orchids in Uttarakhand, Western Himalayas, India. International Journal of Plant Biology 3:e5:24–26.

Jalal, J. S., G. S. Rawat and Y. P. S. Pangtey. 2010. Current status of orchids in Uttarakhand and strategies for their conservation. Pp. 387–396. *in* L. M. Tewari, Y. P. S. Pangtey, and G. Tewari, (eds.) *Biodiversity Potentials of the Himalaya.* Gyanodaya Prakashan, Nainital.

Karger, D. N., J. Kluge, T. Krömer, A. Hemp, M. Lehnert, and M. Kessler. 2011. The effect of area on local and regional elevational patterns of species richness. Journal of Biogeography 38:1177–1185.

Kato, M. 2007. Distribution of Osmundaceae. Bulletin of the National Museum of Natural Science, Series B 33:81–90.

Kato, M. and C. Tsutsumi. 2008. Generic classification of Davalliaceae. Acta Phytotaxonomica et Geobotanica 59:1–14.

Kessler, M., B. S. Parris, and E. Kessler. 2001. A comparison of the tropical montane pteridophyte floras of Mount Kinabalu, Borneo and Parque Nacional Carrasco, Bolivia. Journal of Biogeography 28:611–622.

Kessler, M., J. Kluge, A. Hemp, and R. Ohlemüller. 2011. A global comparative analysis of elevational species richness patterns of ferns. Global Ecology and Biogeography 20:868–880.

Khine, P. K., C. Fraser-Jenkins, S. Lindsay, D. Middleton, G. Miehe, P. Thomas, and J. Kluge. 2017. A contribution toward the knowledge of ferns and lycophytes from Northern and Northwestern Myanmar. American Fern Journal 107:219–256.

Khullar, S. P. 1994. *An Illustrated Fern Flora of the West Himalaya, Volume I.* International book distributing Co., Lucknow, India.

Khullar, S. P. 2000. *An Illustrated Fern Flora of the West Himalaya, Volume II.* International book distributing Co., Lucknow, India.

Kessler M., L. Salazar, J. Homeier, and J. Kluge. 2014. Species richness-productivity relationships of tropical terrestrial ferns at regional and local scales. Journal of Ecology 102:1623–1633.

Kluge J. and M. Kessler. 2011. Phylogenetic diversity, trait diversity and niches: species assembly of ferns along a tropical elevational gradient. Journal of Biogeography 38:394–405.

Kluge, J., M. Kessler. and R. R. Dunn. 2006. What drives elevational patterns of diversity? A test of geometric constraints, climate and species pool effects for pteridophytes on an elevational gradient in Costa Rica. Global Ecology and Biogeography 15:358–371.

Kramer, K. U. 1990. Notes on the higher-level classification of the recent ferns. Pp. 49–52. *in* K. U. Kramer, and P. S. Green, (eds.) *Pteridophytes and Gymnosperms.* Springer, Berlin, Heidelberg.

Mehltreter, K. 1995. Species richness and geographical distribution of montane pteridophytes of Costa Rica, Central America. Feddes Repertorium 106:563–584.

Misra, R. 1968. *Ecology workbook.* Oxford & IBH Publishing Co., Calcutta.

Moran, R. C. and A. R. Smith. 2001. Phytogeographic relationships between neotropical and African-Madagascan pteridophytes. Brittonia 53:304–351.

Nayar, B. K. 1974. Classification of homosporous ferns part II. Pp. 111–201. *in* B. K. Nayar and S. Kaur, (eds.) *Companion to R. H. Beddome's Handbook to the ferns of British India, Ceylon and the Malaya Peninsula.* Chronica Botanica, New Delhi.

Pandey, P. C. and H. C. Pandey. 2003. Fern Allies of Uttaramchal: Checklist. Phytotaxonomy 3:66–74.

Patil, S., R. Lavate, V. Rawat, and M. Dongare. 2016. Diversity and distribution of pteridophytes from Satara District, Maharashtra (India). Plant Science Today 3:149–156.

Pichi Sermolli, R. E. G. 1977. Tentamen Pteridophytorum genera in taxonomicum ordinem redigendi. Webbia 31:313–512.

Piekos-Mirkowa, H. and A. Delimat. 2002. Occurrence of *Woodsia alpina* (Athyriaceae) in the Tatra Mts. Polish Botanical Journal 47:41–44.

Punetha, N. 1989. Ecological and phytogeographical observations on the fern flora of Pithoragarh district (North-west Himalaya). Proceedings of the Indian Academy of Sciences 98:327–333.

Punetha, N. and S. Kaur. 1987. Pteridophytic flora of Pithoragarh district of Kumaon (West Himalayas). Journal of Economic and Taxonomic Botany 9:269–286.

Raychaudhri, S. P., R. R. Agarwal, N. R. Datta Biswas S. P. Gupta, and P. K. Thomas. 1963. *Soils of India.* ICAR, New Delhi.

Raunkiaer, C. 1934. *The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer.* CAB International: New Delhi, India.

Salazar, L., J. Homeier, M. Kessler, S. Abrahamczyk, M. Lehnert, T. Krömer, and J. Kluge. 2015. Diversity patterns of ferns along elevation in Andean tropical forests. Plant Ecology and Diversity 8:13–24.

Shukla, G. and S. Chakravarty. 2012. Fern diversity and biomass at Chilapatta reserve forest of West Bengal Terai Duars in sub-humid tropical foothills of Indian eastern Himalayas. Journal of Forestry Research 23:609–613.

Singh, C., S. Garkoti, and H. C. Pande. 2013. Ecology of fern wealth (Pteridophyta) of Dehradun district, Uttarakhand, India. Annals of Plant Sciences 2:327–341.

Singh, K. N., L. B. Gopichand, and N. P. Todaria. 2015. Ecological status and conservation of rare plants in high altitude landscapes of Indian Western Himalaya. Global Journal of Research on Medicinal Plants and Indigenous Medicine 5:1–18.

Smith, A. R., K. M. Pryer, E. Schuettpelz, P. Korall, H. Schneider, and P. G. Wolf. 2008. Fern classification. Pp. 417–467 *in* T. A. Ranker and C. H. Haufler, (eds.) *Biology and Evolution of Ferns and Lycophytes.* Cambridge University Press, Cambridge.

Sureshkumar, J. M. Ayyanar and R. Silambarasan. 2019. Pteridophyte species richness along elevation gradients in Kolli Hills of the Eastern Ghats, India. Journal of Asia-Pacific Biodiversity; doi.org/10.1016/j.japb.2019.11.008

Tanaka, T. and T. Sato. 2013. Elevational patterns of fern species assemblages and richness in central Japan. Plant Ecology 214:1189–1197.

Tryon, R. M., A. F. Tryon, and K. U. Kramer. 1990. Pteridaceae. Pp. 230–256 *in* K. U. Kramer and P. S. Green, (eds.) *The families and genera of vascular plants. Vol. 1. Pteridophytes and Gymnosperms.* Springer: Berlin.

Tsutsumi, C., C.-W. Chen, A. Larsson, Y. Hirayama, and M. Kato. 2016. Phylogeny and classification of Davalliaceae on the basis of chloroplast and nuclear markers. Taxon 65:1236–1248.

Tuomisto, H. 2010. A diversity of beta diversities: straightening up a concept gone awry. Part 1. Defining beta diversity as a function of alpha and gamma diversity. Ecography 33:2–22.

Upreti, K., J. S. Jalal, L. M. Tewari, G. C. Joshi, Y. P. S. Pangtey, and G. Tewari. 2009. Ethnomedicinal uses of Pteridophytes of Kumaun Himalaya, Uttarakhand, India. Journal of American Science 5:167–170.

Wadia, D. N. 1945. Soils of India. Journal of Scientific and Industrial Research 3:359–367.

Watkins Jr., J. E., C. Cardelus, R. K. Colwell, and R. C. Moran 2006. Species richness and distribution of ferns along an elevational gradient in Costa Rica. American Journal of Botany 93:73–83.

Young, K. R. and B. Leon. 1991. Diversity, ecology and distribution of high-elevation pteridophytes within Rio Abiseo National Park, North-Central Peru. Fern Gazette 14:25–39.

Yusuf, F. B., B. C. Tan and I. M. Turner. 2003a. Species richness of Pteridophytes in natural versus man-made lowland forests in Malaysia and Singapore. *in* S. Chandra, and M. Srivastava, (eds.) *Pteridology in the New Millenium.* Kluwer Academic Publishers, Dordrecht, Boston, London.

Yusuf, F. B., B. C. Tan and I. M. Turner. 2003b. What is the minimum area needed to estimate the biodiversity of pteridophytes in natural and man-made lowland forests in Malaysia and Singapore. Fern Gazette 17:1–9.

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The *Platycerium* Variant from Mount Lewis, Australia

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Abstract.—The *Platycerium* plants circulating amongst hobbyists and growers under the common name *Platycerium* 'Mount Lewis' is the same plant as the cultivar known as *Platycerium* 'Venose Frond', or, as it was later called, *Platycerium willinckii* var. *venosum*. This plant also shares the trait of raised major veins with *P. bifurcatum* var. *lanciferum*, described in 1915. Morphological and molecular comparisons of this plant were made with members of the *P. bifurcatum* complex, particularly with *P. bifurcatum* and *P. willinckii*, to determine its true identity. We conclude that *Platycerium* 'Mount Lewis' is a variant of *P. bifurcatum*.

Key Words.—*Platycerium bifurcatum*, *P.* 'Mount Lewis', *P. willinckii* 'Venose Frond', *P. bifurcatum* var. *lanciferum*, *P. bifurcatum* 'Mt. Lewis'

Platycerium species have always intrigued the horticultural public and the search for new species or garden variants is a perpetual quest. Following one of his many visits to Australia, Loran Whitelock introduced into cultivation in the United States a *Platycerium* found at the top of Mt. Lewis, north Queensland, Australia. The plant looked different from other *Platycerium* plants in current cultivation: its semi-pendant fertile fronds have raised major veins on the abaxial surface, sunken major veins on the adaxial surface, and the wide-spreading upper extension of the base frond is highly lobed (Fig. 1). It was informally named and widely known amongst growers as the 'Mt. Lewis Plant'. Ralph Hughes, a *Platycerium* grower from Fort Meyers, Florida, gave this plant the formal cultivar name *P. willinckii* 'Venose Frond' (formerly *P. bifurcatum* subsp. *willinckii* 'Venose Frond'), which may be shortened to *P.* 'Venose Frond' (Hughes, 1987). Later, Hughes supplanted the cultivar name to a botanical variety name: *P. willinckii* var. *venosum* (formerly *P. bifurcatum* subsp. *willinckii* var. *venosa* R.H. Hughes [*nom. inval.*]) (Hughes, 1989). Finally a plant was described in 1915 that partially matched the Mt. Lewis *Platycerium* with respect to visible major veins on the abaxial side of the fertile fronds, and was named *P. bifurcatum* var. *lanciferum* Domin (Domin, 1915).

The basic features of the Mt. Lewis *Platycerium* place it in the *P. bifurcatum* complex, and most growers refer to it as *P. willinckii* T. Moore when referring to it at the species level. However, with some characters and the geographic distribution more closely favoring *P. bifurcatum* (Cav.) C.Chr., there were some doubts about its true identity. Basic and more detailed characteristics of *Platycerium* species in general have been described for reference (Hoshizaki,

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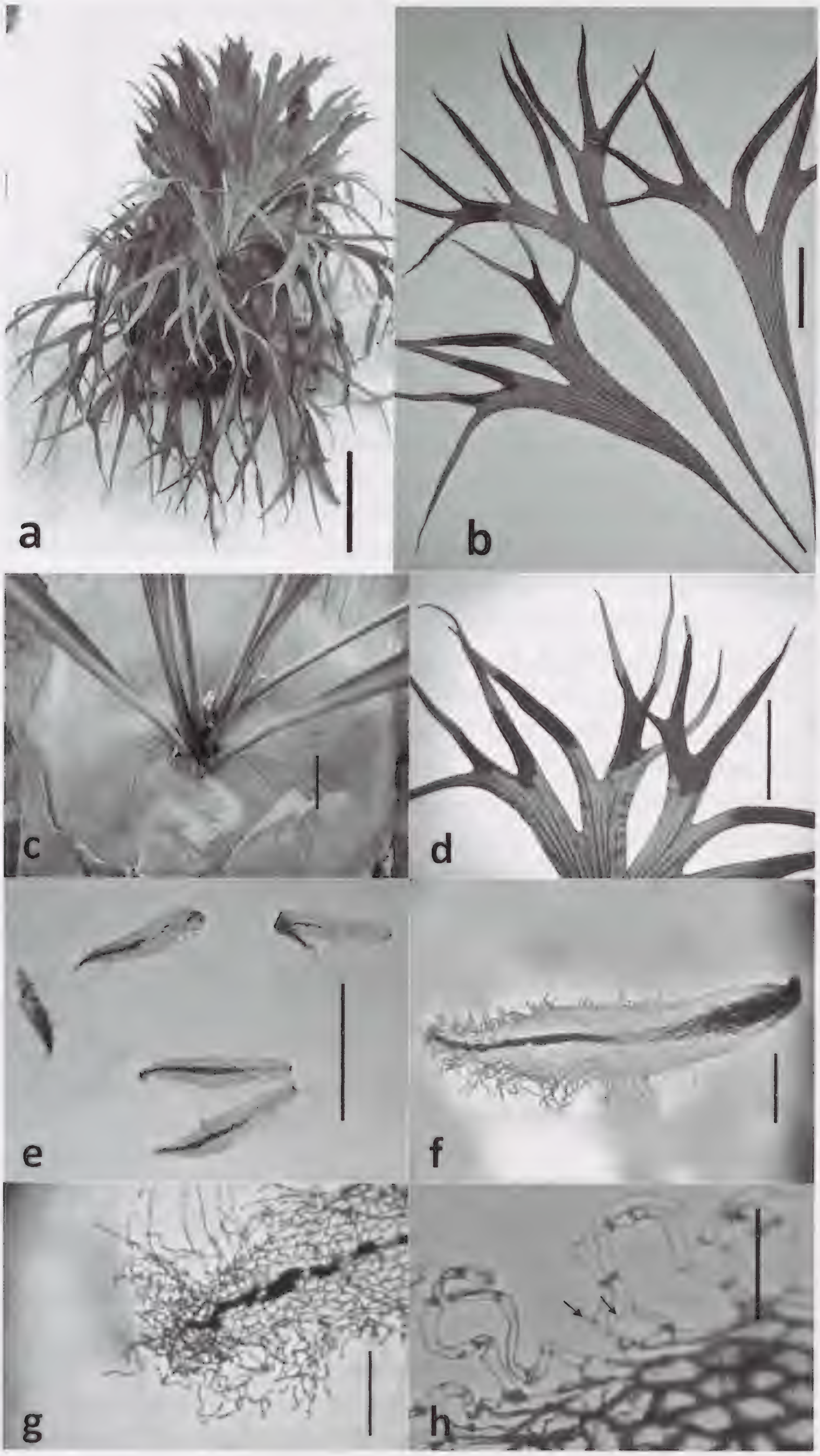

FIG. 1. *Platycerium* 'Mt. Lewis'. a. Habit (Scale line = 20 cm). b. Fertile fronds (Scale line = 10 cm). c. Slender stipes (Scale line = 10 mm). d. Soral patch positions and raised major veins (Scale line = 10 cm). e. Rhizome scales (Scale line = 5 mm). f. Rhizome scale, enlarged. (Scale line = 1 mm). g. Rhizome scale apex multicellular with many filaments (Scale line = 0.4 mm). h. Rhizome scale indument with protuberances, see arrow (Scale line = 0.1mm).

1972; Hoshizaki and Moran, 2001), as well as details of Australian *Platycerium* species (Andrews, 1990; Bostock and Spokes, 1998; Jones and Clemesha, 1980). In this paper we present both morphological and molecular (cpDNA) data to determine the species of *Platycerium* 'Mt. Lewis'.

Materials and Methods

A detailed morphological comparison was made between all of the recognized and putative taxa described for the *Platycerium bifurcatum* complex using mature living cultivated plants grown outdoors in Los Angeles, California. Where possible, natively collected plants were also examined. Fully mature plants and their characteristics were examined because they were observed to vary less than immature plants. The most commonly observed states for each feature of the *Platycerium* taxa examined were summarized to differentiate between them. The *Platycerium* 'Mt. Lewis' used in this study, was a pup or clone from Whitelock's original wild collected plant on Mt. Lewis, Australia.

Total DNA was extracted from cultivated *Platycerium* 'Mt. Lewis' leaf tissue using the DNeasy Plant Mini Kit from QIAGEN (Valencia, California, USA), and the purified DNA was then used as a template to amplify three chloroplast loci (*rbcL, rps4,* and the *rps4-trnS* intergenic spacer [IGS]), using the polymerase chain reaction (PCR). The reactions were carried out with Pfu DNA polymerase from New England Biolabs (Ipswich, MA, USA) according to manufacturer's protocols using the primers brun2 (CATTACCTTCACGAG-CAAGGTCACGG) and brun3 (TTATCGATTGACCTATTACACTCC) for the *rbcL* loci, and the primers rps5 (Nadot et al. 1994) and trnS (Souza-Chies et al., 1997) for the *rps4* and *rps4-trnS* IGS loci. The PCR products were purified using the MinElute Reaction Cleanup kit from QIAGEN and then subjected to DNA sequencing on an ABI3730xl DNA Analyzer. All sequences were deposited in GenBank (Table 1). Distance trees were generated on GenBank, and used to determine the relationship of the *P.* Mt. 'Lewis' DNA sequences to those of members of the *P. bifurcatum* complex available on the database (Table 1).

Results

Morphological comparisons.—Base or Humus Collecting Fronds — *Platycerium* base fronds are usually distinct for each species, and often used as a general diagnostic. Typical base fronds of *Platycerium* 'Mt. Lewis' are best observed on fully mature robust plants. As a young plant matures, successive fronds change shape from round to oblong having the upper margin moderately extended and lobed. Subsequent fronds produce an increasingly taller extension that spreads upward and eventually turns outwards, bearing aloft the marginal forks and lobes (Fig. 1a). On fully mature plants, the fronds may bend to a nearly horizontal position about where the now deeply cut forks and lobes begin on the frond.

TABLE 1. DNA sequence information used in this study.

Species	Plastid DNA loci	GenBank Accession	Voucher	Ref.
P. 'Mt. Lewis'	*rbcL*	MN701979	UC/JEPS	This report.
P. bifurcatum	*rbcL*	DQ164447	CG0403	Kreier and Schneider, 2006
P. bifurcatum	*rbcL*	AF470341	UCBG 87.0172	Haufler et al., 2003
P. bifurcatum	*rbcL*	KY632839	Wei X.P. 41503	Wei et al., 2017
P. hillii	*rbcL*	DQ164452	CG0407	Kreier and Schneider, 2006
P. veitchii	*rbcL*	DQ164460	CG0413	Kreier and Schneider, 2006
P. willinckii	*rbcL*	DQ164463	C. Alford*	Kreier and Schneider, 2006
P. 'Mt. Lewis'	*rps4+rps4-trnS*	MN788518	UC/JEPS	This report
P. bifurcatum	*rps4+rps4-trnS*	DQ164478	CG0403	Kreier and Schneider, 2006
P. hillii	*rps4+rps4-trnS*	DQ164483	CG0407	Kreier and Schneider, 2006
P. veitchii	*rps4+rps4-trnS*	DQ164491	CG0413	Kreier and Schneider, 2006
P. willinckii	*rps4+rps4-trnS*	DQ164494	C. Alford	Kreier and Schneider, 2006

* C. Alford, Charles Alford Rareferns Nursery.

A comparison of the Mt. Lewis base frond to other members of the *Platycerium bifurcatum* complex is shown in Table 2. The *P. willinckii* base fronds (Fig 2a) closely match those seen in *P.* 'Mt. Lewis', with their ample arching extension and deeply cut lobes and forks, which explains why many horticulturalists label *P.* 'Mt. Lewis' as *P. willinckii.* Such base fronds are absent in the other taxa of the *P. bifurcatum* complex. In the remaining three taxa of the complex, the base frond features are typically distinct enough to separate them from each other.

THE FERTILE FROND.—Members of the *Platycerium bifurcatum* complex all have fronds that are forked one to several times, with the divisions typically long and strap-shaped, except in *P. hillii* T. Moore, where they are short. The soral patches are typically located on the unmodified terminal lobe, but they may extend lower. Beyond this description, each taxon has its own typical fertile frond features, though sometimes subtle and variable. Fertile frond features, seen on live plants but seldom seen on herbarium specimens, include the orientation or position of the frond while still attached to the plant, the color of the fresh foliage, and the presence or absence of raised veins.

Fertile frond features most distinctive in *Platycerium* 'Mt. Lewis' include the gently arched and semi-pendant position of the fronds (Fig. 1a), the well-developed slender stipes (Fig. 1b–c), the dark green color, the slender branches of the forks and ultimate lobes (Fig. 1b), the blade's abaxial surface with raised major veins (Fig. 1d), and the adaxial surface with sunken major veins. Older plants tend to bear many fertile fronds.

A comparison of the fertile fronds of *P.* 'Mt. Lewis' with members of the *P. bifurcatum* complex is shown in Table 2. Although there is some character overlap, no species in the *P. bifurcatum* complex has all distinguishing fertile frond characteristics of *P.* 'Mt. Lewis'. *Platycerium willinckii* can be further differentiated from the other taxa because the base of the frond is twisted to a near vertical position, then becomes sharply pendant; the long fertile fronds (to

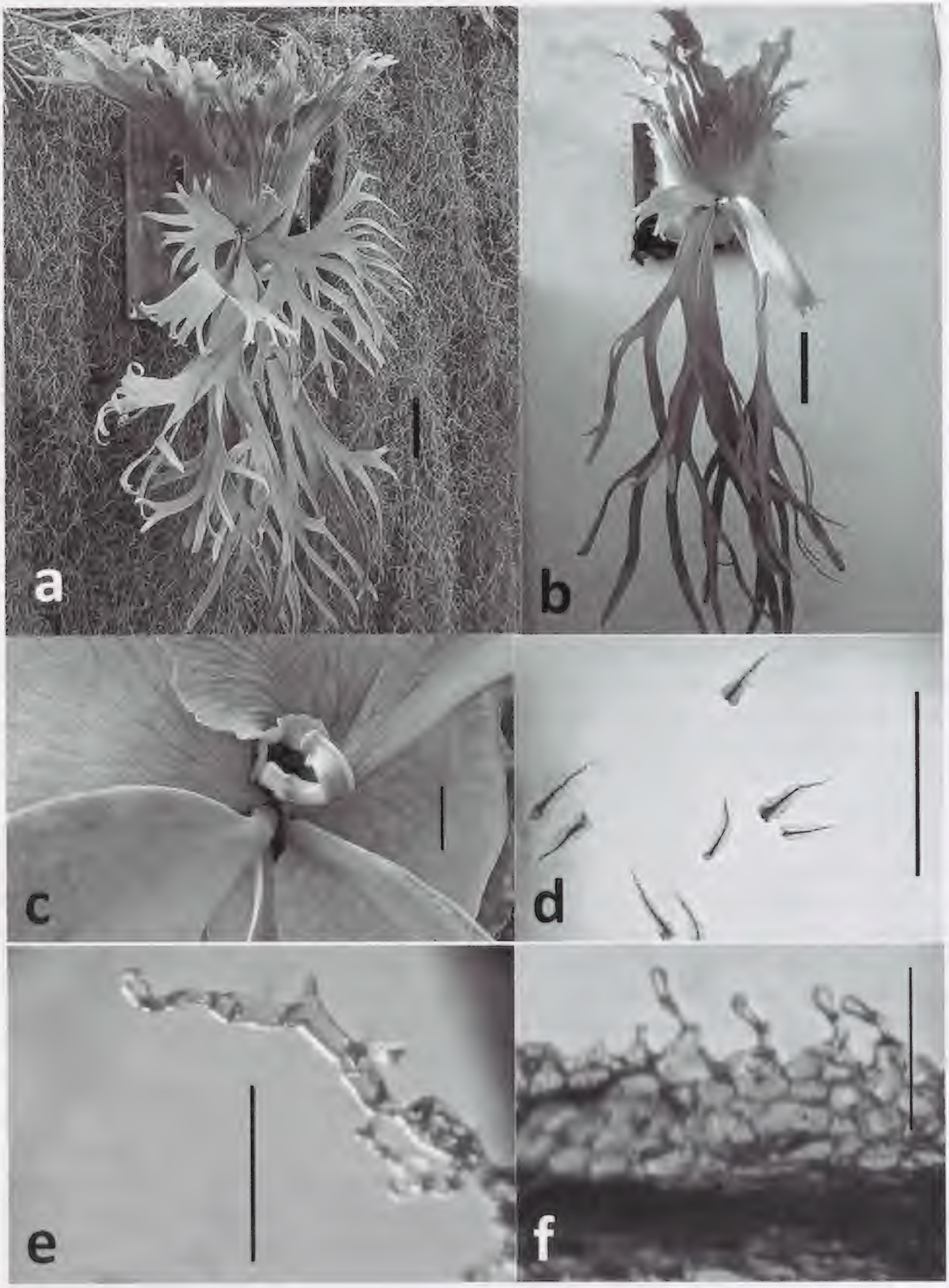

FIG. 2. *Platycerium willinckii*. a. Habit of older mature plant (Scale line = 10 cm). b. Habit, variation in mature plant (Scale line = 15 cm). c. Fronds sessile or with short stipe, blade thick, oriented vertically (Scale line = 2 cm). d. Rhizome scales (Scale line = 5 mm). e. Rhizome scale apex filiform, gland tipped (Scale line = 0.3 mm). f. Rhizome scale indument, regularly spaced along margin (Scale line = 0.3 mm).

TABLE 2. Comparing the *Platycerium bifurcatum* taxa.

Base frond characters	**Mt. Lewis**	***bifurcatum***	***hillii***	***veitchii***	***willinckii***
Upper extension of base frond.	yes	yes	_	yes	yes
Extension long, deep cut forks and lobes spreading forward.	yes	_	_	_	yes
Extension medium-long, cut forks, narrow, stiff and erect.	_	_	_	yes	_
Upper margin modestly extended, sinuate to shallowly lobed.	_	yes	_	_	_
Fertile frond characters	**Mt. Lewis**	***bifurcatum***	***hillii***	***veitchii***	***willinckii***
Fronds gently arched to semi pendant.	yes	yes	_	_	_
Fronds usually erect, may arch apically.	_	_	yes	yes	_
Fronds sharply pendant from near base.	_	_	_	_	yes
Blades not tending to twist at base.	yes	yes	yes	yes	_
Blades tending to twist at base to a near vertical plane.	_	_	_	_	yes
Stipe to 2 cm long or more, slender, distinct.	yes	_	_	_	_
Stipe usually shorter, stouter, or absent.	_	yes	yes	yes	yes
Blade medium to long (to 75 cm).	yes	yes	yes	yes	_
Blade mostly long (more than 75 cm).	_	_	_	_	yes
Blade dark green.	yes	_	_	_	_
Blade green.	_	yes	yes	_	_
Blade whitish-gray green.	_	_	_	yes	yes
Forks starting in proximal 2/3 frond.	yes	yes	_	yes	yes
Forks starting in distal 1/3–1/4 of frond.	_	_	yes	_	_
Branches of ultimate forks and lobes slender to 2 cm wide.	yes	_	_	_	_
Branches of ultimate forks and lobes wider.	_	yes	yes	yes	yes
Major abaxial veins distinctly raised, adaxial sunken.	yes	_	_	_	_
Major abaxial veins not raised, or if raised, not sunken adaxially.	_	yes	yes	yes	yes
Rhizome scale features	**Mt. Lewis**	***bifurcatum***	***hillii***	***veitchii***	***willinckii***
Rhizome scales mostly more than 5 mm.	yes	yes	yes	yes	_
Rhizome scale length 5 mm or less.	_	_	_	yes	yes
Scale apex mostly multicellular, blunt, tipped with mass of straight to contorted filaments.	yes	yes	yes	_	_
Scale apex usually a filament, often obscured.	_	_	_	yes	_

TABLE 2. Continued.

Rhizome scale features	Mt. Lewis	*bifurcatum*	*hillii*	*veitchii*	*willinckii*
Scale apex a filament, 4–6 cells long.	_	_	_	_	yes
Marginal indument filaments, 4–6 cells long, contorted, unevenly spaced.	yes	yes	yes	yes	_
Marginal indument filaments, 2–5 cells long, straight or bent, evenly spaced.	_	_	_	_	yes
Geographical distribution	**Mt. Lewis**	***bifurcatum***	***hillii***	***veitchii***	***willinckii***
Eastern Australia.	yes	yes	yes	yes	_
Indonesia.	_	yes	_	_	yes

100 cm) are a whitish grey-green color (Fig. 2a–c). Main features separating *P. willinckii* from *P.* 'Mt. Lewis' include its stouter or absent stipe, absence of raised abaxial veins, and broad ultimate forks and lobes.

In summary from the preceding description, the fertile frond features of *Platycerium* 'Mt. Lewis' do not closely match any particular taxa of the *P. bifurcatum* complex (Table 2).

RHIZOME SCALES AND THEIR INDUMENT.—Rhizome scales of *Platycerium* were found to have distinguishing features and have been studied earlier (Hennipman and Roos, 1982; Hoshizaki, 1970). The rhizome scales of *P.* 'Mt. Lewis' were mostly narrow triangular to oblanceolate, 5.0–8.5 mm long (Fig. 1e). The typical scale had an apex that was multicellular, acute to blunt and tipped with many filaments (Fig. 1f). In some cases, the filaments are congested and form a tangled mass (Fig. 1g). The marginal indument consisted of mostly long and slender filaments, usually 5–6 cells long, tipped with a colorless roundish to oblong gland-like cell (Fig. 1h).

A comparison of the *Platycerium* 'Mt. Lewis' rhizome scales with other species in the *P. bifurcatum* complex with respect to scale length, apex, marginal indument, and indument spacing is shown in Table 2. *Platycerium willinckii* shows marked differences in length of scale (Fig. 2d), scale apex (Fig. 2e), marginal indument, and indument spacing (Fig. 2f).

Molecular analysis.—Molecular data were generated to augment the morphological studies. *Platycerium* 'Mt. Lewis' DNA sequences were obtained for three chloroplast loci, *rbcL, rps4*, and the *rps4-trnS* IGS.

The *Platycerium* 'Mt. Lewis' *rbcL* sequence was compared to all the *P. bifurcatum* complex *rbcL* sequences in the NCBI database. This includes single entries for *P. willinckii, P. hillii, P. veitchii* (Underw.) C.Chr. , and three for *P. bifurcatum* (Table 1). The *P.* 'Mt. Lewis' sequence clusters with the *P. bifurcatum* sequences, and is distant from *P. willinckii* (Fig. 3).

The *Platycerium* 'Mt. Lewis' combined sequence for *rbcL, rps4,* and the *rps4-trnS* IGS was compared to combined sequences from the same vouchers for *P.*

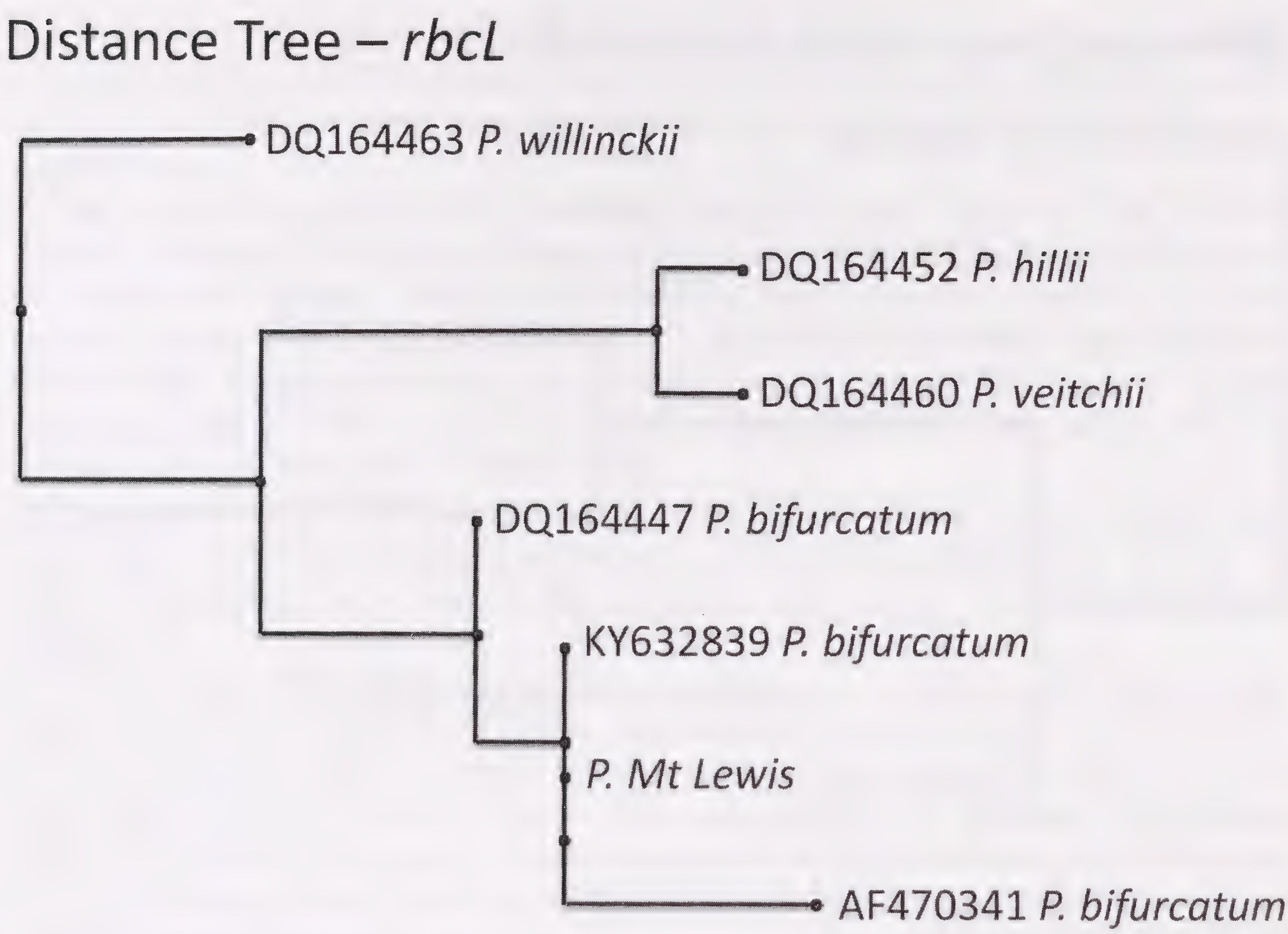

Fig. 3. Distance tree showing the relationship of *Platycerium* 'Mt. Lewis' to members of the *P. bifurcatum* complex based on *rbcL* sequences in the NCBI database (see table 1).

willinckii, P. hillii, P. veitchii., and *P. bifurcatum* (Kreier, 2006) (Table 1). *P.* 'Mt. Lewis' is closest to *P. bifurcatum* and distant from *P. willinckii* (Fig 4).

Habitat and geographical distribution.—Whitelock first collected *Platycerium* 'Mt. Lewis' near the summit of Mt. Lewis, North Queensland, Australia, circa 1980 (personal communication). Mount Lewis (1,200 m elevation) is located about 60 km northwest of Cairns. The ferns were growing in very wet montane tropical rainforest. Similar plants were also found on Mt. Fraser, and Mt. Spurgeon, in Mt. Hypipamee National Park, Mt. Windsor Tableland, and the area around Millaa Millaa. Whitelock related that even high in the trees the outline of this fern was distinct. The wide spreading deeply lobed base fronds made him think it was *P. superbum*, but his view through binoculars revealed the presence of offshoots, a feature of the *P. bifurcatum* complex.

Domin's earlier sightings.—Domin (1915) named *P. bifurcatum* var. *lanciferum* and his description at least partially matched the fertile frond of *P.* 'Mt. Lewis'. The only feature that Domin described was the fertile frond. It was greatly dichotomously divided; the segments strongly elongate, oblong, linear-acuminate, narrow, to 2 cm wide; the length of the segments extending longer, frequently to 15 cm and spore bearing. Domin's accompanying figure clearly shows the narrow elongated shape of the fertile frond. This figure also

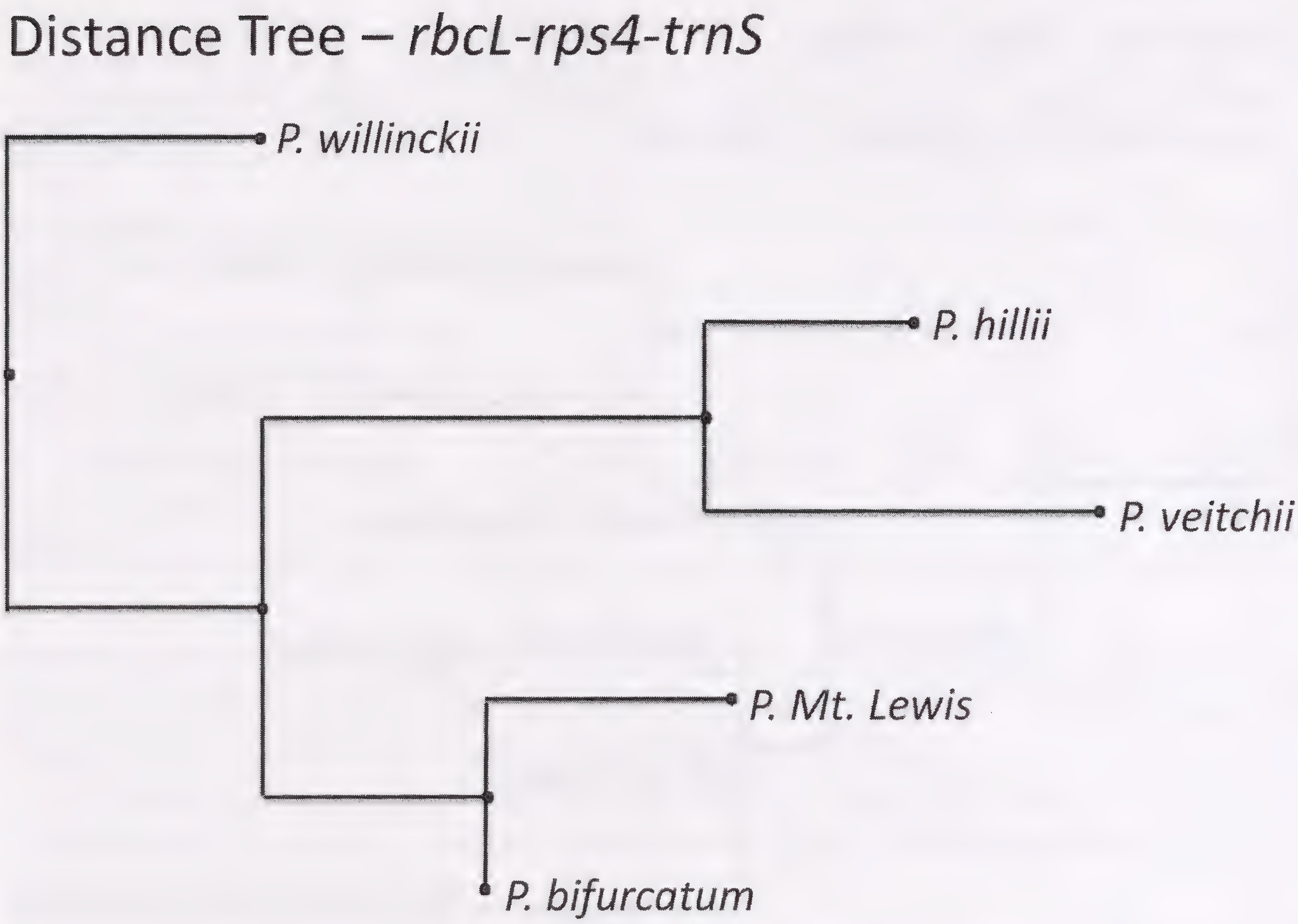

FIG. 4. Distance tree showing the relationship of *Platycerium* 'Mt. Lewis' to members of the *P. bifurcatum* complex based on combined sequences for *rbcL, rps4*, and the *rps4-trnS* IGS from the same vouchers (see table 1).

reveals the abaxial side of the frond with soral patches and major veins. There is no mention of adaxial sunken major veins on the fertile frond, or anything about the base frond. Domin's illustrated frond was collected in 1910 at Yarrabah, about 10 km east of Cairns. Another frond was reported collected by Domin in the Tambourine Mountains, near Brisbane.

A live *Platycerium bifurcatum* var *lanciferum* plant (located at the Longwood Gardens, Kennett Square, PA 19348) closely matches Domin's description, with narrow pendant fertile fronds. A pressed fertile frond from this plant shows abaxial raised major veins, but live fertile fronds do not reveal adaxial sunken major veins. Also absent is the wide-spreading, deeply lobed upper extension of the base frond that is one of the hallmarks of *P.* 'Mt. Lewis'.

DISCUSSION

An unusual looking *Platycerium* in the *P. bifurcatum* complex was found on Mt. Lewis, Australia, with narrow, elongated, semi-pendant fertile fronds, raised major veins on the abaxial surface of the fertile frond, sunken major veins on the adaxial side of the fertile frond, and a wide-spreading base frond upper extension with deep-cut forks and lobes. Several other sightings were eventually recorded elsewhere in Australia and this attractive fern has entered

the horticultural trade, although determination of the species has remained uncertain. The goal of this report was to identity the position of *P.* 'Mt. Lewis' within the *P. bifurcatum* complex using both morphological and molecular characters.

The major morphological characters analyzed for clues to the species identity included the general shapes of the base and fertile fronds, and features of the rhizome scales. The forward-arching, deeply-cut base frond of *P.* 'Mt. Lewis' closely matched that found in *P. willinckii*, while the semi-pendant, non-twisted fertile frond did not closely match any of the species in the complex. The *P.* 'Mt. Lewis' rhizome scales, however, showed a definite affinity with *P. bifurcatum* and *P. hillii.*

Three chloroplast DNA sequences of *P.* 'Mt. Lewis' (*rbcL, rps4*, and the *rps4-trnS* IGS) were generated, and when compared to sequences of the *P. bifurcatum* complex in the NCBI database, they clearly clustered with *P. bifurcatum.*

We conclude that *Platycerium* 'Mt. Lewis' is a *P. bifurcatum* variant and cultivar. The 1915 report by Domin describes *P. bifurcatum* var. *lanciferum* as having narrow elongated fertile fronds, which presumably led him to name this variant after a lance or sword. The only connection between *lanciferum* and 'Mt. Lewis' is a figure in Domin's report that shows veins on the abaxial side of the fertile frond. Domin does not mention raised major abaxial veins or sunken adaxial veins of the fertile frond, or wide-spreading deeply lobed and wavy upper extensions of the base frond. These are all major characters of 'Mt Lewis'. A live plant of *P. bifurcatum* var *lanciferum* at Longwood Gardens explains why Domin neglected to describe these characters: with the exception of the fertile frond abaxial veins, these other defining characters are all missing. Hughes (Hughes, 1989) later described the 'Mt. Lewis' plant and noted all the features: semi-pendant fertile fronds with major abaxial raised veins and adaxial sunken veins, and the *P. willinckii*-like highly lobed and wavy upper extension of the base frond. This striking latter feature was one of the first things Whitelock noticed from a distance when he discovered this fern, and it is also why Hughes and so many horticulturists have misidentified this plant as *P. willinckii.* While a formal variant name remains unresolved, until the time that it is, horticulturists can at least correct the species on their labels to *Platycerium bifurcatum* 'Mt. Lewis'.

Acknowledgements

Barbara Joe Hoshizaki is fondly remembered by many of us. The international fern community will always be grateful for her willingness to share her knowledge, her time, and her energy with experts and amateurs alike. Shortly before her passing in 2012, Barbara submitted the first version of this paper to The American Fern Journal. The review process was completed later, and this is a revised version of her original article.

The authors thank Loran Whitelock for his help in checking this manuscript and providing natively collected plants for study. All of us are in debt to him for introducing this overlooked plant to cultivation. Having live plants to examine has brought var. Mt. Lewis out of botanical obscurity, established its uniqueness and enhanced the collection of many *Platycerium* growers.

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Literature Cited

Andrews, S. B. 1990. Ferns of Queensland. Pp. 285–288. Queensland Department of Primary Industries, Brisbane, Australia.

Bostock, P. D. and T. M. Spokes. 1998. Polypodiaceae. Pp. 487–489, in A.E. Orchard and P.M. McCarthy (eds.), Flora of Australia. Volume 48. Ferns, Gymnosperms and Allied Groups. Australian Biological Resource Study, Canberra, Australia

Domin, K. 1915. Beitrage zur Flora und Pflanzengeographie Australiens. 1:198, ill. 203.

Haufler, C. H., W. A. Grammer, E. Hennipman, T. A. Ranker, A. R. Smith, and H. Schneider. 2003. Systematics of the ant-fern genus *Lecanopteris* (Polypodiaceae): Testing phylogenetic hypotheses with DNA sequences. Systematic Botany 28:217–227.

Hennipman, E. and M. C. Roos. 1982. A monograph of the fern genus *Platycerium* (Polypodiaceae). North-Holland Publishing Co., Amsterdam, Netherlands.

Hoshizaki, B. J. 1970. The rhizome scales of *Platycerium*. American Fern Journal 60:144–160.

Hoshizaki, B. J. 1972. Morphology and phylogeny of *Platycerium* species. Biotropica 4:93–117.

Hoshizaki, B. J. and R. C. Moran. 2001. Fern Growers Manual. Pp. 427–437. Timber Press, Portland, Oregon, United States.

Hughes, R. H. 1987. A new variety of *Platycerium bifurcatum* (Cav.) C. Chr. subsp. *willinckii* (T. Moore) Hennipman & Roos. Pteridologist 1:158–159.

Hughes, R. H. 1989. A new variety of *Platycerium bifurcatum* subsp. *willinckii*. LAIFS Fern Journal 16:74–75.

Jones, D. L. and S. C. Clemesha. 1980. Australian Ferns and Fern Allies. Pp 180–183. The Currawong Press, Australia.

Kreier, H.-P. and H. Schneider. 2006. Phylogeny and biogeography of the staghorn fern genus *Platycerium* (Polypodiaceae, Polypodiidae). American Journal of Botany 93:217–225.

Nadot, S., R. Bajon, and B. Lejeune. 1994. The chloroplast gene *rps4* as a tool for the study of Poaceae phylogeny. Plant Systematics and Evolution 191:27–38.

Souza-Chies, T.T., G. Bittar, S. Nadot, L. Carter, E. Besin, and B. Lejeune. 1997. Phylogenetic analysis of Iridaceae with parsimony and distance methods using the plastid gene *rps4*. Plant Systematics and Evolution 204:109–123.

Wei, X., Y. Qi, X. Zhang, L. Luo, H. Shang, R. Wei, H. Liu, and B. Zhang. 2017. Phylogeny, historical biogeography and characters evolution of the drought resistant fern *Pyrrosia* Mirbel (Polypodiaceae) inferred from plastid and nuclear markers. Nature: Scientific Reports 7, article number:12757.

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Two New Species of *Doryopteris* (Pteridaceae) from Brazil

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Abstract.—Two new species of *Doryopteris* from Brazil are described and illustrated: *Doryopteris spiritu-sanctensis,* a monomorphic species endemic to low and middle elevation coastal forests in Espírito Santo, and *Doryopteris alata,* a small dimorphic species endemic to high elevation, rocky fields within the savannas (cerrados) of Goiás.

Resumo.—Duas espécies novas de *Doryopteris* do Brasil são aqui descritas e ilustradas: *Doryopteris spiritu-sanctensis,* uma espécie monomórfica das florestas costeiras do Espírito Santo, ocorrendo em baixas e médias elevações; e *Doryopteris alata,* uma pequena espécie dimórfica endêmica aos Campos Rupestres do Cerrado de Goiás, ocorrendo em altas elevações.

Key Words.—Atlantic Forest, Brazilian savanna, cerrado, Espírito Santo, Goiás

Doryopteris J. Sm. is a remarkable fern genus belonging to the Pteridaceae, subfam. Cheilanthoideae (PPG I, 2016). Because of its pedate and palmate leaves, it is considered by some one of the most beautiful genera of ferns. Traditionally, *Doryopteris* comprised two sections (*Doryopteris* and *Lytoneuron*) with about 30–40 species (Brade, 1964; Tryon, 1942). Recent phylogenetic studies have demonstrated this classification to be artificial (Yesilyurt and Schneider, 2010; Yesilyurt *et al.*, 2015). To preserve monophylly, the Paleotropical species were accommodated in the recently described *Calciphilopteris, Lytoneuron* was raised to genus level, *Ormopteris* was resurrected (and showed to be closely related to these genera), and *Doryopteris* had its circumscription narrowed (Yesilyurt and Schneider, 2010; Yesilyurt *et al.*, 2015). In this new circumscription (*sensu* Yesilyurt *et al.*, 2015), *Doryopteris s. str.* has 15–25 species, occurring exclusively in South America (with the exception of the widespread *D. concolor* (Langsd. & Fisch.) Kuhn), and with its main center of diversity in southeastern Brazil. The number of species in the genus is still unknown, due to three diverging taxonomic revisions on the genus: Tryon (1942) listed eight species of *Doryopteris* sect. *Doryopteris* (≈ *Doryopteris s. str.*); Brade (1964) raised the number of species to 16 with eight varieties; and Yesilyurt (2003) recognized 20 species. Adding further complications, Sehnem (1972) described several hybrids from southern Brazil, which were not taken into account in the previous and subsequent literature.

While analyzing specimens that have not been included in the existing taxonomic literature (specially from under-sampled regions in Brazil), we

noticed two undescribed species. It is not surprising that they are new for three reasons: First, southeastern Brazil is the center of diversity of the genus; second, the state of Espírito Santo has recently been target to taxonomic study of ferns, which has resulted in many new species being described, including a *Lytoneuron* (*e.g.*, Labiak and Matos, 2009; Salino *et al.*, 2016; Schwartsburd, Miranda, and Prado, 2016; Smith-Braga and Schwartsburd, 2020); and third, the fern flora of the Brazilian savanna (cerrado), including the state of Goiás, is still poorly known.

Material and Methods

We analyzed specimens from BHCH, CESJ, MBML, OUPR, RB, VIC, and VIES. We also analyzed specimens (including types) from virtual herbaria at: JSTOR (https://www.jstor.org/), Kew Gardens (htpp://www.kew.org/), Muséum National D'Histoire Naturelle (http://www.mnhn.fr/), Reflora (http://reflora.jbrj.gov.br/reflora/herbarioVirtual/ConsultaPublicoHVUC/ConsultaPublicoHV12UC.do), and SpeciesLink database (http://www.splink.org.br/index?lang=pt).

To visualize venation, we cleared leaves with bleach. To visualize vascular bundles in the petioles, we made cross sections in the proximal and medial portions of the petioles. The line drawings were prepared by Reinaldo Pinto.

The maps were drawn using the software DIVA-GIS v. 7.5 (Hijmans, 2013). For collections with no coordinate data, we estimated locations through searches in Google Earth (https://www.google.com.br/intl/pt-PT/earth/). In the maps we also used a layer containing the Brazilian Biomes, available at the IBGE website (https://mapas.ibge.gov.br/interativos/servicos/wms-do-arcgis.html). We repainted the layer to evidence the Atlantic Forest and the cerrado in gray scale.

Results and Discussion

Doryopteris spiritu-sanctensis A.G.S. Oliveira & Schwartsb., **sp. nov.** Type: BRAZIL. Espírito Santo: Santa Leopoldina, Morro Agudo, propriedade da Dona Maria, 20°05′38″S, 40°25′54″W, 150–350 m, 18 May 2006, *L.F.S. Magnago, V. Demuner, T. Cruz & E. Bausen 1049* (holotype: MBML!). (Figs. 1A–E, 2A, B).

Diagnosis.—Differs from *Doryopteris raddiana* by the monomorphic leaves (*vs.* dimorphic), fertile leaves with 2–4 pairs of primary segments (*vs.* 5–7 pairs), with basal segments with only basiscopic secondary segments (*vs.* with acroscopic and basiscopic secondary segments).

Plants terrestrial or epipetric. *Rhizomes* short-creeping; *scales* bicolorous, centrally black, with hyaline margins, opaque, linear-lanceate. *Leaves* monomorphic, the fertile ones only taller than the vegetative ones; *petioles* atropurpureous to blackish, terete, rugose, proximally with scales similar to those from the rhizomes, otherwise sparsely scaly to glabrous, with one

vascular bundle internally; *laminae* herbaceous, glabrous; *laminar buds* absent; *veins* anastomosing. *Vegetative leaves* 14–28 cm long; *petioles* 7–16 cm long; *laminae* pedate or pedatissect, 7–12 × 10–13 cm; *basal segments* with 1–3 secondary segments in the basiscopic side, these lobed to pinnatifid; *medial segments* lobed; *lobes* rounded; *hydatodes* visible in the adaxial side of laminae; *laminar margins* crenate. *Fertile leaves* 17–42 cm long; *petioles* 10–30 cm long; *laminae* 7–12 × 11–15 cm, pedate or pedatissect, with 2–3 pairs of primary segments; *costae* proximally tripartite, visible for all their extension, proximally dark brown to blackish; *basal segments* with 1–3 secondary segments in the basiscopic side, these lobed to pinnatifid; *medial segments* lobed; *lobes* rounded to triangular; *costal wings* parallel to costae; *sori* interrupted in the sinuses and in the apex of segments; *indusia* hyaline.

Ecology and distribution.—Endemic to the coastal and mid elevation forests of Espírito Santo; 150–600 m (Figs. 2A, B).

Etymology.—The specific epithet is ethnic, referring to the distribution of the species, which is probably endemic to Espírito Santo ("*Spiritus Sanctus*" in Latin).

Additional Specimens Examined (Paratypes).—BRAZIL. Espírito Santo: Cariacica, Reserva Biológica Duas Bocas, 8 Jan 2007, *L. Kollmann et al. 9405* (MBML); Santa Leopoldina, Fazenda Caioaba, 20°03′33"S, 40°28′14"W, 17 Jul 2007, *R.R. Vervloet et al. 2899* (MBML); Santa Teresa, Estrada do 25 de Julho, Terreno do Casotti, 6 Apr 1999, *L. Kollmann et al. 2398* (MBML); Santa Teresa, São João de Petrópolis, Mata do São Bráz, 19°49′54"S, 40°44′11"W, 28 Aug 2012, *N.T.L. Pena et al. 43* (MBML); Santa Teresa, São João de Petrópolis, Mata do São Bráz, 19°49′55"S, 40°44′13"W, 28 Aug 2012, *N.T.L. Pena et al. 51* (MBML); Serra, 19 Nov 1988, *M. Álvaro s.n.* (MBML-006396).

Due to the monomorphic leaves, *Doryopteris spiritu-sanctensis* is morphologically closer to those species belonging to the *Doryopteris pedata* complex, which Raddi (1819, 1825) treated as *Pteris pedata* L. var. [α], *β*, and *γ*. These were later treated by Tryon (1942) as *D. pedata* (L.) Fée var. "*typica*" (var. α), *D. pedata* var. *multipartita* (Fée) R.M. Tryon (var. *γ*), plus *D. pedata* var. *palmata*. Then, Pichi-Sermolli and Bizzarri (2005), when re-analyzing Raddi's works (1819, 1825) further changed their names to *D. pedata s. str.* (not occurring in Brazil), *D. pentagona* Pic.-Serm. (var. α), *D. stieri* Rosents. (var. *β*), and *D. raddiana* (C. Presl) Fée (var. *γ*). Yesilyurt (2003) considered as valid *D. palmata, D. pedata, D. pentagona, D. raddiana,* and *D. stieri* – although Yesilyurt *et al.* (2015) further omitted *D. raddiana*. According to Flora do Brasil (2020), *D. palmata* and *D. pedata* do not occur in Brazil; *D. pentagona* is widespread in Brazil and adjacent countries; *D. raddiana* is endemic to southern and southeastern Brazil; and *D. stieri* in endemic to the two southernmost states of Brazil (and possibly adjacent countries). Of all these taxa belonging to the *Doryopteris pedata* complex, only *D. pentagona, D. raddiana,* and *D. spiritu-sanctensis* occur in the state of Espírito Santo (Oliveira 2019; Flora do Brasil, 2020).

Doryopteris spiritu-sanctensis differs from the Antillean *D. pedata s. str.* by the atropurpureous to black petioles (*vs.* reddish-brown), which are glabrous

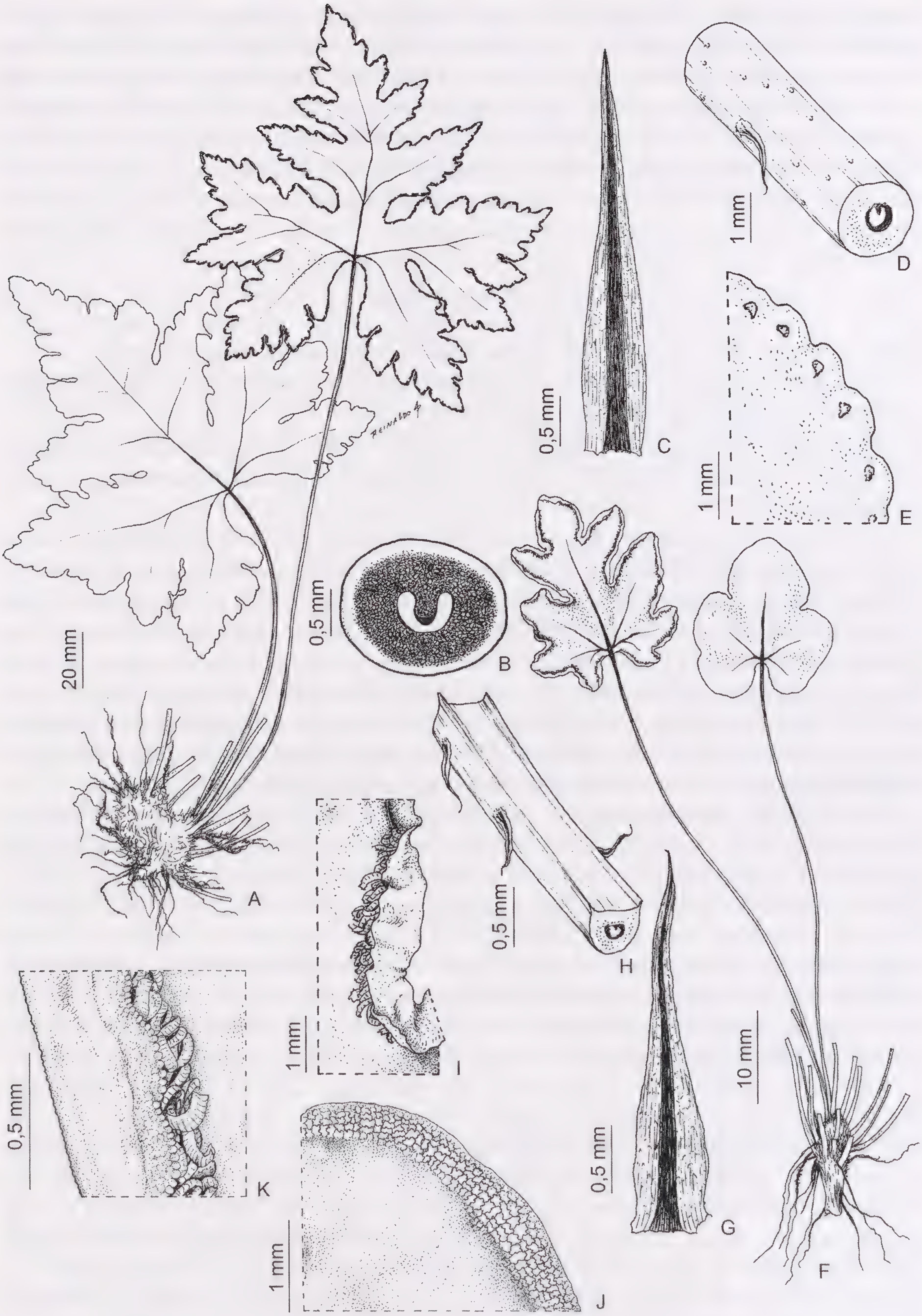

FIG. 1. Two new species of *Doryopteris* from Brazil. **A–E.** *Doryopteris spiritu-sanctensis* (*Magnago et al. 1049*). **A.** Habit, showing vegetative (left) and fertile (right) leaves. **B.** Petiole in cross section,

Fig. 2. Two new species of *Doryopteris* from Brazil. **A.** Map of Brazil showing the biomes Atlantic Forest (light gray) and cerrado (dark gray), and the distribution of *Doryopteris spiritu-sanctensis* (black circles) and *Doryopteris alata* (black triangles). **B.** Distributions in detail.

←

showing one vascular bundle. **C.** Rhizome scale. **D.** Petiole in cross section, showing scale, rugosity, and vascular bundle. **E.** Vegetative lamina, adaxial surface, showing hydathodes and crenate margins. **F–I.** *Doryopteris alata* (*Martinelli et al. 3810*). **F.** Habit, showing fertile (left) and vegetative (right) leaves. **G.** Rhizome scale. **H.** Petiole in cross section, showing scales, adaxial wings, and vascular bundle. **I.** Fertile lamina, abaxial surface, showing indusium. **J.** Indusium in detail, showing hyaline, sub-clathrate portion with square and puzzle piece-like cells. **K.** *Doryopteris collina* (*Braga 116*), indusium in detail, showing thin hyaline portion with globose marginal cells.

(*vs.* copiously pilose), and by the segments distally lobed to crenulate (*vs.* distally caudate) (Figs. 1A, D). *Doryopteris spiritu-sanctensis* differs from *D. pentagona* by the glabrous petioles (*vs.* copiously pilose), and by the costal wings parallel to costae (*vs.* cuneiform costal wings) (Figs. 1A, D).

Doryopteris spiritu-sanctensis differs from *D. stieri* by the basal segments with lobed to pinnatifid secondary segments, basiscopically (*vs.* entire secondary segments), by the lobed medial segments (vs. entire medial segments), and by the sori interrupted in the sinuses and in the apex of segments (*vs.* sori continuous throughout the lamina) (Fig. 1A). Finally, *Doryopteris spiritu-sanctensis* differs from *D. raddiana* by the monomorphic leaves (*vs.* dimorphic), fertile leaves with 2–4 pairs of primary segments (*vs.* 5–7 pairs), with basal segments with only basiscopic secondary segments (*vs.* with acroscopic and basiscopic secondary segments), and with broad costal wings, 0.8–1 cm wide (*vs.* narrow wings, less than 0.5 cm wide) (Fig. 1A).

Doryopteris alata A.G.S. Oliveira & Schwartsb., **sp. nov.** TYPE: BRAZIL. Goiás: Alto Paraíso de Goiás, 43 Km ao norte de Alto Paraíso de Goiás, Chapada dos Veadeiros, formações de campos rupestres, 1200 m, 24 Jan 1978, *G. Martinelli et al. 3810* (holotype: RB-206758!). (Figs. IF–I, 2A, B).

Diagnosis.—Differs from *Doryopteris collina* by the broad, membranaceous, hyaline, sub-clathrate indusia to 0.5 mm wide (*vs.* coriaceous, green indusia with a short hyaline margin to 0.15 mm wide, which is non clathrate); differs from *Doryopteris apparicioi* by the reddish-brown, lustrous, winged petioles (*vs.* black, opaque, unwinged petioles).

Plants epipetric. *Rhizomes* erect to decumbent; *scales* bicolorous, centrally brown to reddish-brown, hyaline at the margins, lustrous, linear-lanceolate. *Leaves* dimorphic; *petioles* reddish-brown, lustrous, canaliculate, with reddish-brown adaxial wings, smooth, with sparse scales similar to those from the rhizomes, with sparse minute, glandular hairs, with one vascular bundle internally; *laminae* leathery, glabrous; *laminar buds* absent; *veins* anastomosing. *Vegetative leaves* 4–7 cm long; *petioles* 3.5–5.5 cm long; *laminae* palmate, 3–5 lobed, 0.7–1.5 × 0.8–1.5 cm; *lobes* rounded; *hydathodes* not visible; *laminar margins* smooth to wavy. *Fertile leaves* 6.5–8.5 cm long; *petioles* 5.5–7 cm long; *laminae* pedate or pedatissect, with 1–2 pairs of primary segments, 1–1.5 × 1–1.5 cm, *basal segments* with 1–3 basiscopic lobes; *costae* proximally tripartite, visible only proximally where they are reddish-brown; *costal wings* parallel to the costae; *sori* continuous along the sinuses, interrupted at the segment apices; *indusia* broad, membranaceous, hyaline, sub-clathrate, to 0.5 mm wide, with wavy margins, with square or puzzle piece-like marginal cells.

Ecology and distribution.—Probably endemic to high-elevation, rocky fields within the Brazilian savanna (cerrado); 1000–1200 m (Figs. 2A, B).

Etymology.—The specific epithet *alata* (Latin for *winged*) alludes to the conspicuous and persistent wings present on the adaxial surface of the petioles (Fig. 1H).

Additional Specimens Examined (Paratypes).—**BRAZIL. Goiás:** 20 km E of Pirenópolis, Serra dos Pirineus, 1000 m, 14 Jan 1972, *H.S Irwin et al. 34110* (NY, image!)

Apart from its small leaves (to 8.5 cm long), *Doryopteris alata* is characterized by the lustrous, reddish-brown petioles with conspicuous adaxial wings (Figs. 1F, H)—characteristics shared with the widespread *D. collina* (Raddi) J. Sm. The adaxial wings in *D. alata* are, however, persistent throughout the petioles, whereas in *D. collina* they are caduceus, remaining only distally or detaching in full. *Doryopteris alata* further differs from *D. collina* by its indusia, which are broad, membranaceous, hyaline, sub-clathrate, to 0.5 mm wide, and with square or puzzle piece-like marginal cells (Figs. 1I, J); on the other hand, the indusia of *D. collina* are green and coriaceous with a short hyaline margin to 0.15 mm wide, non-clathrate, and with spherical (glandular?) cells at the margins (Fig. 1K). More obviously, *D. collina* is gigantic compared to *D. alata,* with fertile leaves to 32 cm long (*vs.* to 8.5 cm; Fig. 1F)—although we acknowledge that leaf sizes in *Doryopteris* must be carefully analyzed, especially in specimens from rocky sites; thus, the leaf sizes in *D. alata* must only be established when more collections from Goiás are available.

Another similar species is *Doryopteris apparicioi* Brade, from the Brazilian savanna of Minas Gerais and Goiás, which also has small leaves to 10(–15) cm long, with coriaceous laminae (Flora do Brasil, 2020; Oliveira, 2019). *Doryopteris alata* differs from *D. apparicioi* by rhizome scales with reddish-brown center (*vs.* black center), reddish-brown, lustrous, winged petioles (*vs.* black, opaque, not-winged petioles), and costae only proximally visible (*vs.* visible to 2/3 of their length) (Figs. 1F–H).

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Literature Cited

Brade, A. C. 1964. Contribuição para o conhecimento das espécies brasileiras do gênero *Doryopteris* (Polypodiaceae). Arquivos do Jardim Botânico do Rio de Janeiro 18:39–72.

Flora do Brasil 2020. *under construction. Doryopteris.* Available at: <http://floradobrasil.jbrj.gov.br/reflora/floradobrasil/FB91895>. Accessed on: 17 Jun 2020.

Hijmans, R. J. 2013. DIVA-GIS, a geographic information system for the analysis of biodiversity data. Version 7.5. Available at: http://www.diva.gis.org

Labiak, P. H. and F. B. Matos. 2009. *Cyathea atrocastanea,* a new tree fern from the Atlantic Rain Forest of southeastern Brazil. Systematic Botany 34:476–480. https://doi.org/10.1600/036364409789271326

Oliveira, A. G. S. 2019. *Estudo taxonômico do gênero* Doryopteris *(Pteridaceae) nos estados de Minas Gerais e Espírito Santo, Brasil.* Master Thesis, Universidade Federal de Viçosa, Viçosa, Brazil.

Pichi-Sermolli, R. E. G. and M. P. Bizzarri. 2005. A revision of Raddi's pteridological collection from Brazil (1817–1818). Webbia 60:1–403.

PPG I (The Pteridophyte Phylogenetic Group). 2016. A community-derived classification for extant lycophytes and ferns. Journal of Systematics and Evolution 54:563–603. https://doi.org/10.1111/jse.12229

Raddi, G. 1819. Synopsis filicum Brasiliensium. Opuscoli scientifici d'una Società di professori della Pontifical Università di Bologna 3:279–295.

Raddi, G. 1825. *Plantarum Brasilensium nova genera. Pars I (Filices).* A. Pezzati, Florence, 101 p.

Salino, A., C. J. Leroy, L. C. Moura, and I. O. Moura. 2016. Four new species of the fern genus *Goniopteris* C. Presl (Thelypteridaceae) from Brazilian Atlantic Forest. Phytotaxa 255:249–258. https://doi.org/10.11646/phytotaxa.255.3.6

Schwartsburd, P. B., C. V. Miranda, and J. Prado. 2016. *Oleandra* (Oleandraceae) in the Brazilian Atlantic Forest. American Fern Journal 106:191–205. http://dx.doi.org/10.1640/AFJ-D-16-00004.1

Sehnem, A. 1972. Pteridáceas [PTER]. Pp. 1–244. *In:* R. Reitz (ed.), *Flora Ilustrada Catarinense.*

Smith-Braga, N. S. and P. B. Schwartsburd. 2020. *Lytoneuron* (Pteridaceae) of Minas Gerais and Espírito Santo, Brazil, including descriptions of two new taxa and new combinations. Brittonia 72:362–380. http://dx.doi.org/10.1007/s12228-020-09614-z

Tryon, R. M. 1942. A revision of the genus *Doryopteris.* Contributions from the Gray Herbarium of Harvard University 143:1–80.

Yesilyurt, J. C. 2003. *A systematic revision of the genus* Doryopteris *J. Sm. (Pteridaceae: Cheilanthoideae).* Ph.D. Thesis, University of Reading, Reading, U.K.

Yesilyurt, J. C. and H. Schneider. 2010. The new genus *Calciphilopteris* (Pteridaceae). Phytotaxa 7:52–59.

Yesilyurt, J. C., T. Barbará, H. Schneider, S. Russell, A. Culham, and M. Gibby. 2015. Identifying the generic limits of the Cheilanthoid genus *Doryopteris.* Phytotaxa 221:101–122. http://dx.doi.org/10.11646/phytotaxa.221.2.1

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SHORTER NOTE

Phenological Stages During *In Vitro* Culture of *Microsorum scolopendria* (Burm.f) Copel. from Easter Island.—*Microsorum scolopendria* (Polypodiaceae) (Baeza *et al.*, Boletín del Museo Nacional de Historia Nacional 47:23–26. 1998), known as Matu'a pua'a, is native to Easter Island (Ministry of Environment of Chile, 2010). The creeping rhizome of this species is 5–7 mm in diameter, and bears dark protective scales. The leathery leaves have hard and erect petioles and are oblong-lanceolate (Tejero and Torres, Acta Botánica Mexicana 98:111–124. 2012). In Easter Island as in other areas of the Pacific region it is used as medicinal fern to treat influenza, stomach ache, and strains (Priti, P. K., R. Srivastana, and P. L. Uniyal, The International Journal of Plant Reproductive Biology 8:136–138. 2016). Island natives use it as an ointment to treat injuries. Matu'a pua'a grows on the slopes of Rano Kau volcano and between its crater rocks. Unfortunately, its habitat has been strongly altered by human activity and it has been classified as threatened within Easter Island. *In situ* conservation of this fern is mandatory to establish a viable population. To achieve this, quality propagules from sporophytes must be developed and *in vitro* techniques are the appropriate tools to rescue of these plants (Sarasan, V. Kew Bulletin. 65:549–554. 2010). These techniques play a major role in supporting conservation of species with small populations because they can result in production of sporophytes from a small piece of sporophyte meristem (Pérez-García, B. and I. Reyes Jaramillo, Ciencias 30:11–17. 1993). The aim of this work was to establish an *in vitro* propagation system to increase the population of Matu'a pua'a ferns on Easter Island.

We have accomplished *in vitro* propagation of *M. scolopendria* buds extracted from the rhizome of the plant. Rhizome pieces were washed for 20 minutes in a sodium hypochlorite solution (2% v v^{-1}), buds were extracted and placed in MS medium (Somer, M., R. Arbesú, V. Menéndez, M. A. Revilla, and Helena Fernández. Euphytica 171:203–10. 2010) supplemented with activated charcoal (1 g L^{-1}). The buds were evaluated weekly over a period of four months.

During this period, it was possible to distinguish five phenological stages starting from the initial placement of the buds in the culture medium (F0) until the formation of the young sporophyte (F5). It was also possible to establish the length of each phenological stage during the *in vitro* culture. Between 15 and 80 days after *in vitro* initiation (F0), a green tip in the bud apex appeared and this was classified as phenological stage F1, which lasted for 15–40 days. At stage F2, the bud green tip started to swell and this stage lasted for about 14 days. During the following 14 days, micro-petioles started appearing in the bud called, which we classified as stage F3. At stage F4, micro-petiole elongation occurred and this stage lasted for approximately 21 days. Finally, stage F5 corresponded to development of the young sporophyte (Fig.1).

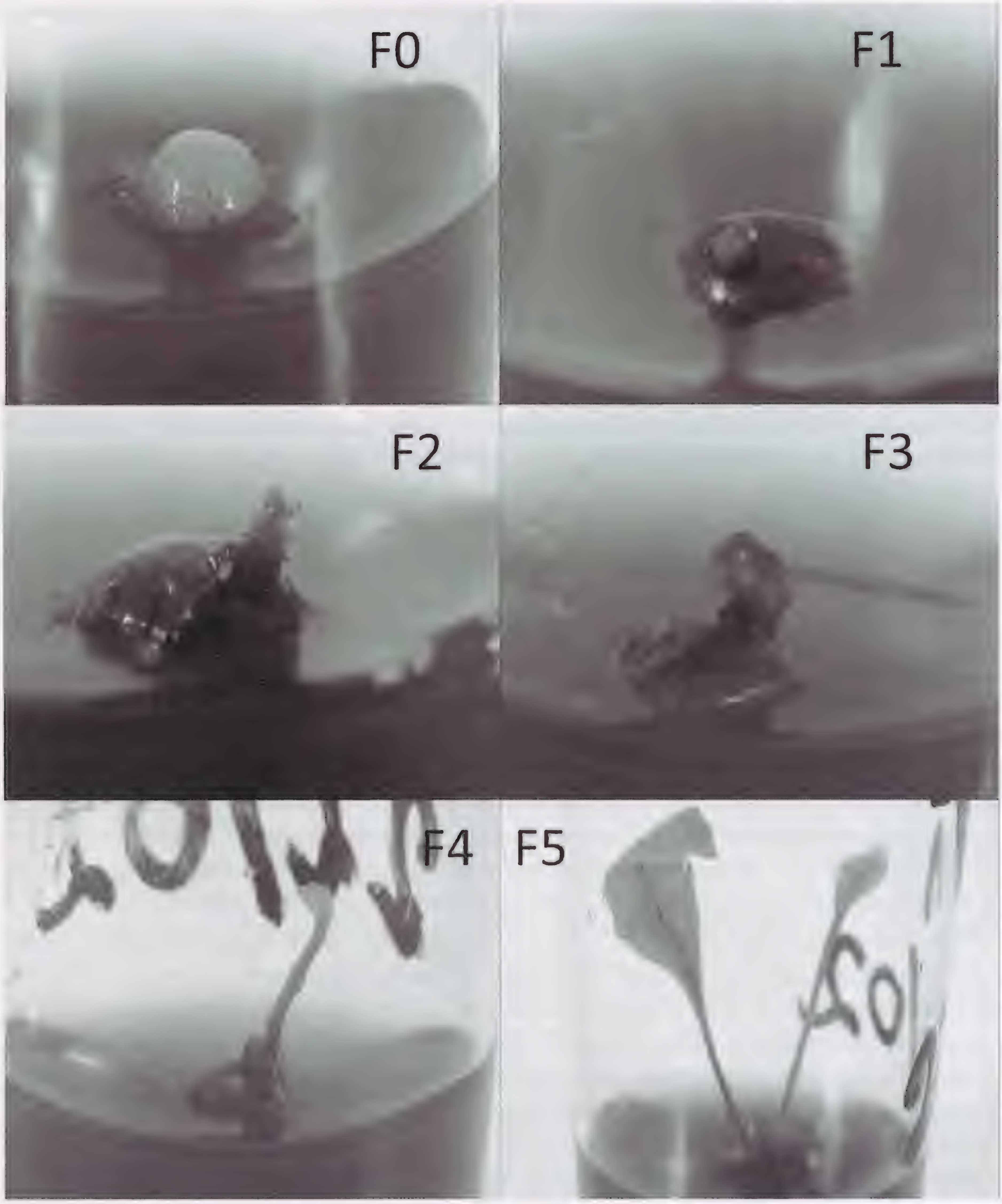

FIG. 1. Phenological stages of *Microsorum scolopendria* during *in vitro* establishment stage. F0 = Bud established; F1 = Green tip stage; F2 = Green tip stage swollen; F3 = Micro-petiole formation; F4 = Micro-petiole elongation; F5 = Young sporophyte.

There is only one reference specifically about *Microsorum scolopendria in vitro* in which spores were used as initial explants in which sowing of spores led to germination in 7–10 days and sporophyte formation was achieved 120 days after germination (Priti, Srivastana, and Uniyal, 2016).

We achieved *in vitro* propagation of *Microsorum scolopendria* from rhizome buds and obtained new sporophytes in a shorter (79 days) to similar (169 days) period than other results. Efforts must be undertaken to enhance bud sprouting to accelerate the whole procedure and obtain mass multiplication of this species to be able to re-establish its population on Easter Island.

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Shorter Note

New Fern and Lycophyte Records from the States of Oaxaca, Zacatecas, Puebla, and San Luis Potosí, Mexico.—Recently, based on herbaria collections from the ENCB (Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional); MEXU (Herbario Nacional de México, Instituto de Biología, Universidad Nacional Autónoma de México); and UAMIZ (Herbario Metropolitano, Universidad Autónoma Metropolitana-Iztapalapa), we have found several species that are reported for the first time from the states of Oaxaca, Puebla, San Luis Potosí, and Zacatecas. Hence, the aim of this article is to point out the species that were not included in the flora "The Pteridophytes of Mexico", published by Mickel and Smith in 2004 (Memoirs of the New York Botanical Garden 88:1-1054.). Of the new records, three species belong to the genus *Diplazium* from Puebla; seven species, within seven genera, were collected in San Luis Potosí; *Woodsia neomexicana* was discovered in Oaxaca and Puebla, and *Asplenium gentryi* from Zacatecas.

It is important to note that the fern flora of Oaxaca is one of the best collected and studied in Mexico; for instance, by Mickel and Beitel (Memoirs of the New York Botanical Garden 46:1-568. 1988), Riba and Lira (Flora del Valle de Tehuacán-Cuicatlán. Fascículo 10. Instituto de Biología. Universidad Nacional Autónoma de México. 1996), Solano Hernández (Polibótanica. 5:37-75. 1997); Tejero-Díez and Mickel (Diversidad Florística de Oaxaca: de musgos a angiospermas. Instituto de Biología. Universidad Nacional Autónoma de México, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Instituto Estatal de Ecología y Desarrollo Sustentable. México. 2012), and Velázquez Montes (Flora del Valle de Tehuacán-Cuicatlán. Fascículo 67. Instituto de Biología. Universidad Nacional Autónoma de México. 2009; Flora del Valle de Tehuacán-Cuicatlán. Fascículo 80. Instituto de Biología. Universidad Nacional Autónoma de México. 2010). Nevertheless, years after Mickel and Smith's (2004) floristic treatment, we found a new record for this state.

The flora of the state of Puebla was studied by Cerón–Carpio *et al.* (Polibótanica 21:45-60. 2006), who reported three genera and 10 species as new records for this state; in 2009, Velázquez Montes studied eight families for the "Flora del Valle de Tehuacán-Cuicatlán"; later, in 2010, he published "Pteridaceae" for the same Flora. Cerón–Carpio *et al.* (2011) published the ferns and lycophytes from Puebla, cited 81 genera and 289 species, which included eight species that are new records; however, they do not cite the scientific name of the new records (La Biodiversidad en Puebla, Estudio de Estado. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado Puebla. Benemérita Universidad Autónoma de Puebla. México. pp. 127-132. 2011). Although the Cuetzalan locality is frequently visited and collected by researchers and students, we have found a small wet

tropical forest, two hours on foot from the Municipality, which holds several species, most of them having gemmae along the leaf.

San Luis Potosí and Zacatecas states are also poorly explored and studied, similar to other places in Mexico. Since the work of Mickel and Smith (2004), few floristic treatments have been published (Pacheco and Sánchez-Morales, American Fern Journal 100:234-237. 2010). Nonetheless, we found seven new records from San Luis Potosí and one from Zacatecas.

New Records

Woodsia neomexicana Windham—México, Oaxaca, Distrito de Huajuapan de León, Municipio de Santa Catarina Zapoquila, Río Grande, (18° 03′N, 97°34′W), 2165 m, 9 Dec 2014, in oak forest. *S. Márquez Bautista 100* (UAMIZ). This locality is not difficult to find but it is quite distant, and the Municipality Authorities and local people demand special permission to allow collectors to explore the area. Puebla, Carretera Teziutlán-Acajete, (19° 09′ 36″N, 97°55′ 43″W), 2670 m, in oak forest. *Villagómez & Corona 8* (UAMIZ). This locality is easy to reach but, frequently, this species is not recognized. This taxon is characterized by its completely filamentous indusial segments, 1-2 celled translucent projections on pinnule margins; largest pinnae with 3-7 pairs of pinnules. In both places, the species was rare, along a small path within the oak forest. Also distributed in USA; in Mexico, it was previously reported from Coahuila, Nuevo León, and Zacatecas states (Mickel and Smith, 2004).

Asplenium gentryi A. R. Sm.—México, Zacatecas, Mpio. Jerez de García Salinas, 2 km from El Cargadero Dam, (22°43′N, 103° 06′W), 2331 m, growing in oak forest, 16 August 2008, *L. Pacheco et al. 3842* (UAMIZ), 16 August 2008, *Jaramillo 65* (UAMIZ). Within the oak forest, this species is abundant, and it also occurs in disturbed areas. In Mexico, it was previously known from Aguascalientes, Chihuahua, Durango, Sinaloa, and Sonora states. Recently, this taxon was also reported from Hidalgo (Guzmán Cornejo *et al.*, Revista Mexicana de Biodiversidad 86:573–581. 2015).

Diplazium altissimum (Jenman) C. Chr.—México, Puebla, Mpio. Cuetzalan, alrededores de Cuetzalan, (20° 01′ N, 97° 33′ W), 520 m, in wet tropical forest, 9 Dec 2013, *L. Pacheco 4034 & Herrera* (UAMIZ). This species differs from *D. diplazioides* (Klotzsch & H. Karst. *ex* Klotzsch) Alston by the presence of buds on the blade apices and at the bases of some pinnules along the costae. The species is rare and distributed along a small river, growing with *D. neglectum* (H. Karst.) C. Chr., *D. striatastrum* Lellinger, and *D. urticifolium* H. Christ. In Mexico, this species was only known from Oaxaca and Chiapas states; Cuba, Jamaica, and Hispaniola (Mickel and Smith, 2004).

Diplazium donnell-smithii H. Christ—México, Puebla: Mpio. Cuetzalan, Cascada de Las Brisas, San Andrés Tzicuilan, (20°00′ 18″N, 97°30′34″W), 850 m, in wet montane forests, *Mendoza 681, Pérez García & Muñiz* (MEXU). This specimen was initially identified as *D. lonchophyllum* Kunze but differs by blades 3-pinnate at least proximally. In México, *D. donnell-smithii* was only

known from Oaxaca and Veracruz states; Guatemala, Honduras, El Salvador, Nicaragua, and Costa Rica (Mickel and Smith, 2004).

Diplazium neglectum (H. Karst) C. Chr.—México, Puebla, Mpio. Cuetzalan, alrededores de Cuetzalan, (20° 00′N, 97° 33′ W), 520 to 670 m, in wet tropical forest, 9 Dec 2013, *L. Pacheco 4050 & L. Herrera* (UAMIZ). This species resembles *D. obscurum* H. Christ but differs by apices pinnatifid and confluent; it also resembles *D. urticifolium* H. Christ, by the largest pinnae, more than 4 cm wide. It was collected in the same locality as *D. obscurum, D. urticifolium, Asplenium delitescens* (Maxon) L. D. Gómez, and *Thelypteris scalaris* (H. Christ) Alston. In Mexico, this taxon was only known from Chiapas state; Costa Rica, Panama, and Colombia (Mickel and Smith, 2004).

Lonchitis hirsuta L.—México, San Luis Potosí, Mpio. Xilitla, camino al Manantial de San Antonio, (21° 22′N, 99° 00′W), 790 m, it grows in wet montane forest, 9 Jan 2014, *L. Pacheco 4052* (UAMIZ), Oct 2013; *Escareño Mendoza 19*, 9 Jan 2014, 55, 61 (UAMIZ). This species is characterized by its hairy rhizomes and petioles, and blades with free veins; the blade when alive is fleshy. It is common in the locality. In Mexico, it was previously known from Puebla, Veracruz, Oaxaca, and Chiapas states; Guatemala to Panama, Great and Lesser Antilles, Colombia, Venezuela, Trinidad, Ecuador, Peru, Brazil, and Bolivia (Mickel and Smith, 2004).

Lygodium heterodoxum Kunze—México, San Luis Potosí, Mpio. Axtla de Terraza, entre Axtla de Terraza y Xilitla, (21° 23′ 58″ N, 98° 57′ 50″ W), 410 m, in wet tropical forest, 9 Jan 2014, *L. Pacheco 4051* (UAMIZ). This fern is common and expected; it is characterized by its reticulate veins. In México, this record from San Luis Potosí, extends its distribution from Chiapas, Oaxaca, Puebla, Tabasco, and Veracruz states; Guatemala, Belize, Honduras, Nicaragua, Costa Rica, and Panama (Mickel and Smith, 2004).

Macrothelypteris torresiana (Gaudich.) Ching—México, San Luis Potosí, Mpio. Xilitla, camino al Manantial de San Antonio, (21° 22′ 16″ N y 99° 00′ 47″ W), 1140 m, in wet montane forests, Oct 2013, *Escareño Mendoza & L. Pacheco 25, 53* (UAMIZ). The two vascular bundles, blades 2-pinnate to 2-pinnate-pinnatifid, distinguishes this species from *Ctenitis* and *Thelypteris*; common in the locality. In México, it was previously known from Chiapas, Estado de México, Oaxaca, Morelos, Querétaro, Tabasco, and Veracruz states, and widespread in the USA, Guatemala, Belize, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, Great and Lesser Antilles, Colombia, Venezuela, Trinidad, Ecuador, Peru, Brazil, Bolivia, Paraguay, and Argentina; as well in Asia, and the Pacific islands (Mickel and Smith, 2004).

Pecluma alfredii (Rosenst.) M. G. Prince **var. *cupreolepis*** (A. M. Evans) A. R. Sm.—México, San Luis Potosí, Mpio. Xilitla, Manantial de San Antonio, (21° 23′ N y 98° 59′ W), 1100 m, in wet montane forests, 5 March 2010, *Viveros 11, 12* (UAMIZ); 5 March 2010, *Tapia, García y García s. n.* (UAMIZ); 5 March 2010, *Luna Vilchis 12* (UAMIZ); 5 March 2010, *Martínez Vidal, Alvarado Arriaga & Hernández García s.n.* (UAMIZ). The reddish brown, ovate rhizome scales, ovate-cordate scales and hairs on the rachises abaxially and pinna margins, distinguish this variety from *P. alfredii* var. *occidentalis*. Common in

the locality. In Mexico, it was previously known from Mexico City, Chiapas, Durango, Guerrero, Hidalgo, Jalisco, Estado de México, Michoacán, Morelos, Oaxaca, Puebla, Sinaloa, and Tamaulipas states; Guatemala, Honduras, El Salvador, Nicaragua, and Costa Rica (Mickel and Smith, 2004).

Pleopeltis alansmithii (R. C. Moran) A. R. Sm. & Tejero—México, San Luis Potosí, Mpio. Xilitla, camino al Manantial de San Antonio, (21° 22′ 16″ N y 99° 00′ 47″ W), 1140 m, in wet montane forest, Oct 2013, *Escareño Mendoza, Herrera & L. Pacheco 20, 21* (UAMIZ). This species has appressed rhizome scales with plain margins, bases of the pinnae decurrent, apices acuminate. Scarce in the locality. In Mexico, it was previously known from Chiapas, Guerrero, and Oaxaca states; Guatemala, Honduras, El Salvador, and Nicaragua (Mickel and Smith, 2004).

Pteris pungens Willd.—México, San Luis Potosí, Mpio. Xilitla, camino al Manantial de San Antonio, (21° 22′ 16″ N, 99° 00′ 47″ W), 790 m, in wet montane forest, Oct 2013, *Escareño & L. Pacheco 14* (UAMIZ). *Pteris pungens* has concolorous rhizome scales, caudate pinna apices, basal veins sometimes arising from the pinna costae, and decurrent terminal pinnae. Scarce in the locality. In Mexico, it was previously known from Chiapas, Oaxaca, and Veracruz states; Guatemala, Belize, Honduras, Nicaragua, Costa Rica, Panama, Greater and Lesser Antilles, Colombia, Venezuela, Trinidad, Guyana, Surinam, French Guiana, Ecuador, Peru, and Bolivia (Mickel and Smith, 2004).

Selaginella flexuosa Spring.—México, San Luis Potosí, Mpio. Xilitla, camino al Manantial de San Antonio, (21° 22′ 16″ N, 99° 00′ 47″ W), 1140 m, in wet montane forest, Oct 2013, *Escareño & L. Pacheco 33, 36* (UAMIZ). *Selaginella flexuosa* has long-aristate white-bordered median leaves; lateral leaves 2-3 mm long, with a minutely denticulate apex and base; non-stoloniferous, non-flagellate, prostrate habit, stilt-like rhizophores, and quadrangular narrow strobili. Scarce in the locality. In Mexico, it was previously known from Oaxaca, Puebla, and Veracruz states; Guatemala, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru, and Bolivia (Mickel and Smith, 2004).

Didymoglossum reptans (Sw.) C. Presl.—México, San Luis Potosí, Mpio. Xilitla, Comunidad de Miramar, Devisadero, (21°23′N y 99°1′ W), 1130 m, in wet montane forest, 3 Jun 2016, *L. Pacheco & Guzmán Cornejo 4071* (UAMIZ). This species was previously recorded from San Luis Potosí by Mickel and Beitel (1988); though, Mickel and Smith (2004) did not report it for the state. However, we recently found it in a small-disturbed wet montane forest.

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Shorter Note

High Phenotypic Variation of *Struthiopteris spicant* (Blechnaceae) at the Edge of Its Range.—Phenotypic variation may be due to genetic and/or environmental causes. Phenotypic plasticity can be defined as a change in the phenotype that is expressed by a single genotype when subjected to different environments (Gratani, Advances in Botany 208747:17 pp. 2014). Despite long debate (Ghalambor *et al.*, Functional Ecology 21:394–407. 2007), many ecologists consider phenotypic plasticity to be an evolutionary strategy for adapting to variable environments, because individuals sense environmental cues in early life stages and express phenotypes that have higher fitness in conditions found later in life (Xue and Leibler, Proceedings of the National Academy of Sciences, USA 115:12745–12750. 2018). In addition, it has been hypothesized that plasticity is more pronounced at the edge of the range of a species or in peripheral populations because they are exposed to high environmental variation where plastic genotypes can be advantageous (Valladares *et al.*, Ecology Letters 17:1351–1364. 2014). However, in seed plants, there is experimental evidence both for (*e.g.*, Lázaro-Nogal *et al.*, Journal of Ecology 103:338–350. 2015) and against (*e.g.,* Berg, Becker and Matthies, Oecologia 143:220–231. 2005) this prediction. As far as we know, this hypothesis has not been tested in ferns, but several studies have analyzed the adaptive significance of phenotypic plasticity in leaf form and function (*e.g.*, Saldaña, Gianoli and Lusk, Oecologia 145:252–257. 2005; Rünk and Zobel, Plant Ecology 193:85–99. 2007).

A special case of leaf plasticity is represented by dimorphism, the ability to produce different sterile and fertile leaves. Dimorphic ferns show reduced laminar area in some part (typically the apex) or in the entire fertile leaf relative to the sterile leaf (Wagner and Wagner, Gardens' Bulletin, Singapore 30:251–267. 1977; Watkins, Churchill, and Holbrook, American Journal of Botany 103:845–855. 2016). Although dimorphism has repeatedly evolved in distinct fern lineages and is present in many species, only rarely has its evolutionary significance been studied (Watkins, Churchill, and Holbrook, 2016). Britton and Watkins (Annals of Botany 118:1139–1149. 2016) concluded that this functional specialization is an adaptation to increase spore dispersal distance and/or spore production, which offsets the costs of photosynthetic decrease due to reduction in photosynthetically active tissues, especially in resource-rich environments.

Struthiopteris spicant (L.) Weiss (Blechnaceae) is a terrestrial or saxicolous fern with markedly dimorphic leaves: the fertile leaves are erect, longer than the sterile, and present heavily contracted pinnae, which have costal cenosori protected by continuous indusia (Rolleri and Prada, Acta Botanica Malacitana 31:7–50. 2006). In Europe, there are two varieties of this species, var. *pradae* S. Molino & Gabriel y Galán (Molino *et al.*, Plant Systematics and Evolution 305:255–268. 2019), and var. *homophyllum* (Merino) Gabriel y Galán & R. Pino (Wasowicz, Gabriel y Galán, and Pino, Phytotaxa 302:198–200. 2017), which

FIG. 1. Representative plants of *Struthiopteris spicant* used in this study. A. Var. *homophyllum* (MA939455). B. Individual intermediate between var. *homophyllum* and var. *spicant* (MACB004769). C. Var. *pradae* (MA939452). D. Individual intermediate between var. *pradae* and var. *spicant* (MACB113878). The four individuals are shown at the same scale. In each individual, an example of each type of leaf is labeled: s, sterile; fc, fertile contracted; fn, fertile non-contracted. The detail shows abaxial surface of medial pinnae, with portions covered (white lines) or not covered (black lines) by cenosori.

show partial or almost complete reversal of dimorphism, respectively (Fig. 1). The var. *homophyllum* comprises small plants, with erect leaves up to 20 cm, usually all sporogenous. Fertile leaves can produce sporangia along all their length, from base to apex, on slightly contracted pinnae, and the cenosori are typically fragmented, with discontinuous indusia (Fig. 1A). The var. *pradae* is

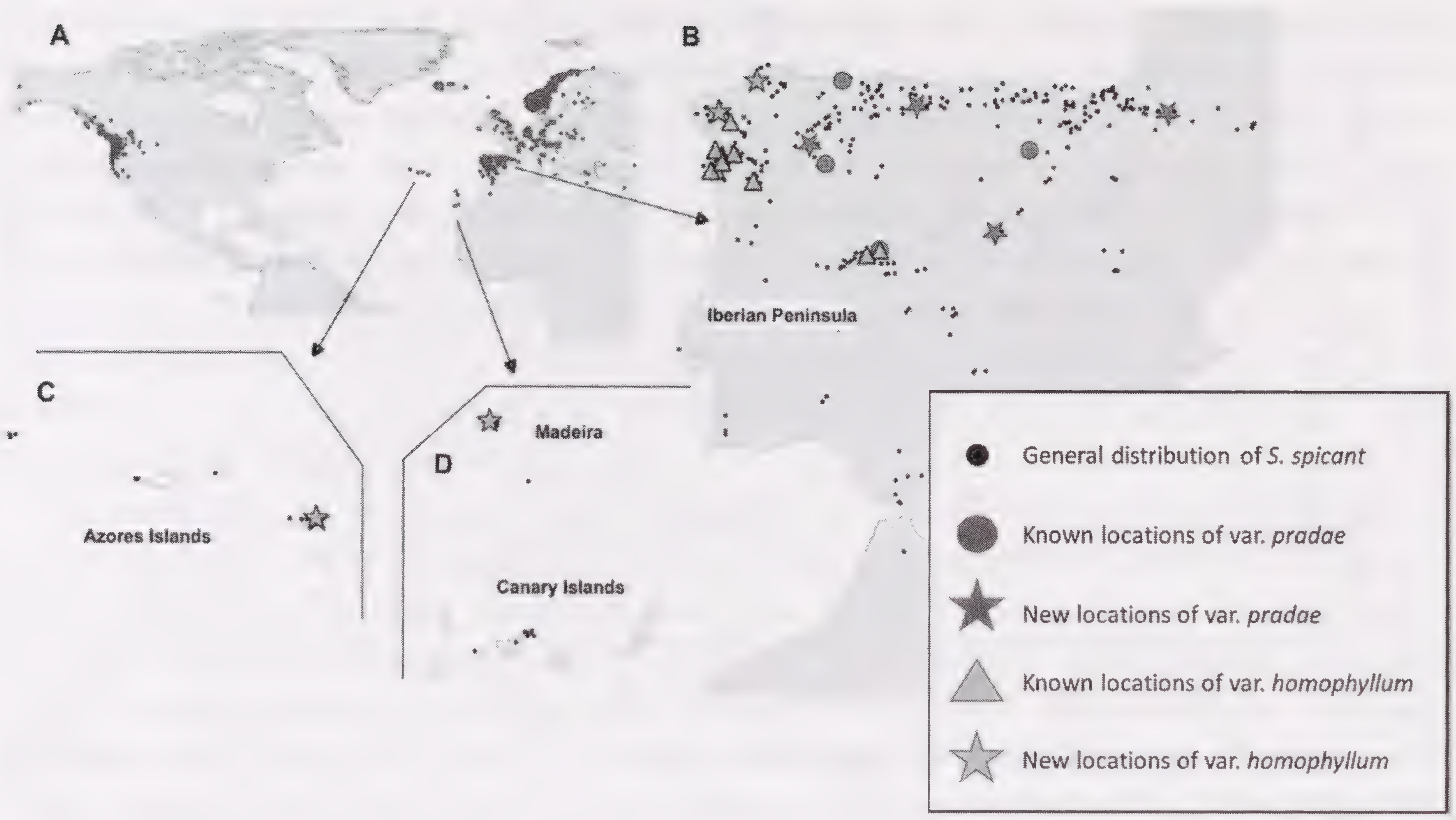

FIG. 2. Distribution of *Struthiopteris spicant* and its Iberian-Macaronesian varieties. A. World distribution of *Struthiopteris spicant*, showing two disjunct centers: Western North America and Central-Western Europe/Macaronesia. B-D. Distributional details in the Iberian Peninsula (B), and Macaronesia: Azores Islands (C) and Madeira/Canary Islands (D). (Source of data of general distribution of *Struthiopteris spicant*: GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset https://www.gbif.org/species/9271606 accessed via GBIF.org on 2019-12-07).

similar in size to the typical variety, but with two distinct types of fertile leaves on the same individual simultaneously: some similar to the typical "fertile *spicant*" leaf, and others more similar to typical "sterile *spicant*", *i.e.* non-contracted, but at least partially sporogenous and with interrupted sori and indusia (Fig. 1C).

Struthiopteris spicant has a wide circumboreal distribution (Fig. 2A), occurring in the Pacific Northwest area of North America (USA: California, Oregon, Washington, Alaska; Canada: British Columbia), throughout central and western Europe (from Sweden, Poland, Ukraine, and Romania westwards to Iceland and the Iberian Peninsula), some parts of northern Africa (where it is rare), and the Macaronesian archipelagos (Canary Islands, Madeira, and Azores Islands). Until now, the varieties *homophyllum* and *pradae* were known only from north of the Iberian Peninsula, which is the southern edge of the European range of *S. spicant* (Fig. 2B). We discovered new locations of both varieties (marked by * in the Appendix), which extend their known distributions beyond this peripheral area in mainland Europe as well as in some Macaronesian islands (S. Miguel and Madeira, which are, respectively, 1500 and 1200 km from the nearest Iberian locations; Figs. 2B, 2C, 2D). In many of these locations, we also observed individuals of var. *spicant* and individuals with intermediate phenotype between this variety and the other variety present there (*homophyllum* or *pradae*; Figs. 1B, 1D). To assess the

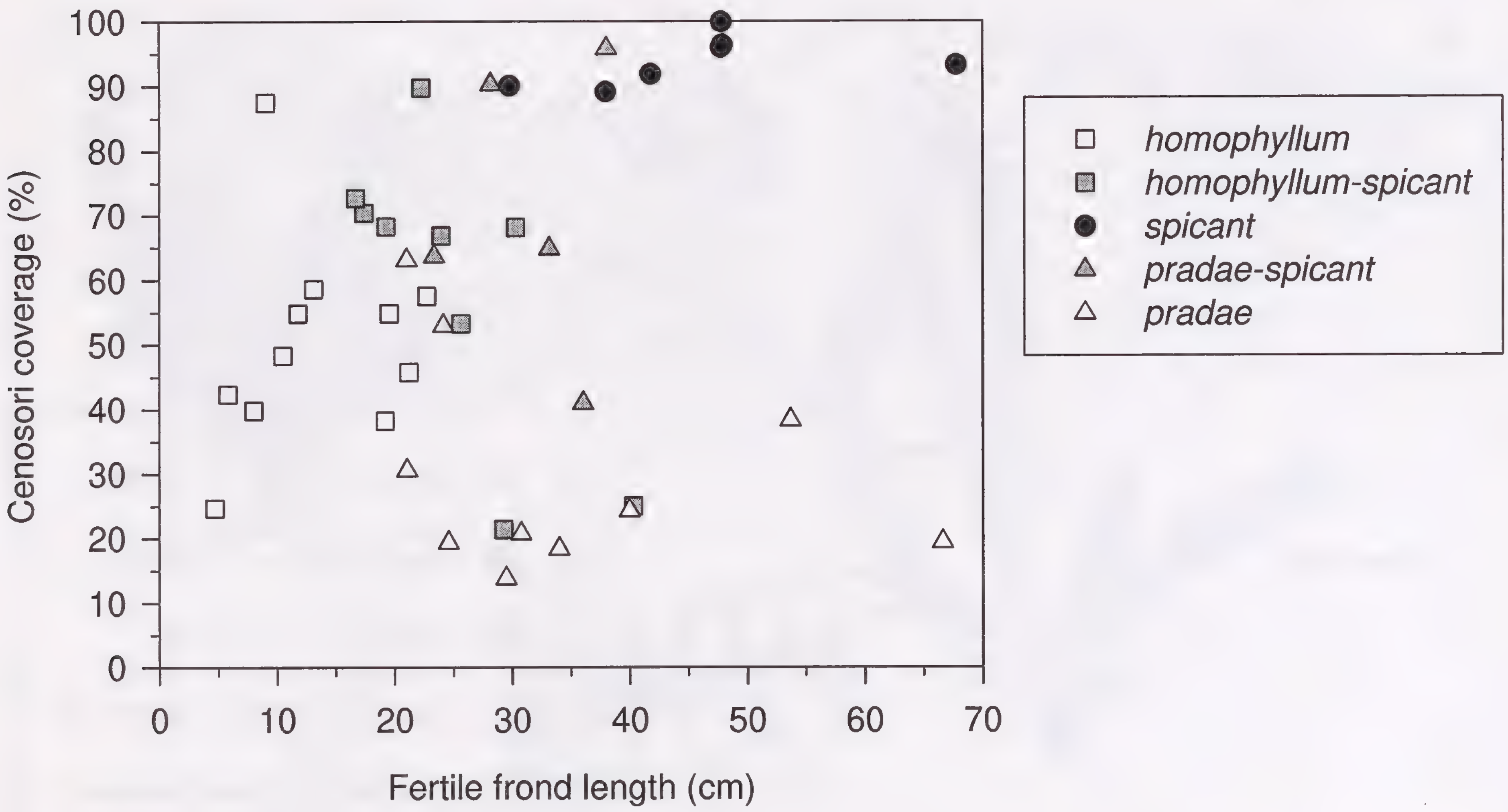

FIG. 3. Variability of two characters of fertile leaves among varieties of *Struthiopteris spicant*. Each dot corresponds to one individual. *homophyllum–spicant* and *pradae–spicant* are individuals with intermediate phenotype between var. *spicant* and var. *homophyllum* or var. *pradae*, respectively.

morphological variation of these populations, we studied two characters, fertile leaf length and cenosori coverage, in a large sample (43 individuals listed in Appendix). We measured the longest fertile leaf of each individual, and cenosori coverage (%) as the portion of the length of all pinnae of a lamina covered by cenosori (Fig. 1). These lengths were obtained on scanned images of leaves with the program ImageJ (Abramoff, Magalhaes, and Ram, Biophotonics International 11:36–42. 2004). For cenosori coverage, we randomly selected one fertile leaf from each individual, of non-contracted type in the cases of var. *pradae* and in intermediate individuals between this variety and var. *spicant*. We analyzed both variables by one-factor ANOVA, with variety as fixed factor, and Tukey tests for subsequent pairwise comparisons. Cenosori coverage was arcsine transformed to improve normality.

The three varieties differed both in fertile leaf length (ANOVA: $F_{2, 26} = 20.14$, $P < 0.0001$) and cenosori coverage ($F_{2, 26} = 53.42$, $P < 0.0001$). Fertile leaves of var. *spicant* (mean ± SE: 45.2 ± 3.9 cm) and *pradae* (34.5 ± 4.8 cm) were similar (Tukey test: $P > 0.05$), whereas those of var. *homophyllum* (13.3 ± 1.9 cm) were significantly shorter (Fig. 3). Cenosori coverage decreased significantly (Tukey tests: $P < 0.05$) in the order var. *spicant* (93.7 ± 1.3 %) > var. *homophyllum* (50.2 ± 4.8 %) > var. *pradae* (30.1 ± 5.2 %). Both characters were highly variable between individuals of each variety, as shown by the high standard errors, and the individuals with intermediate phenotype further widened these ranges of variation (Fig. 3). Our observational data thus give some support to the hypothesis of increased phenotypic plasticity in populations at the edge of ranges. For instance, the populations in the Iberian

Peninsula are under a Mediterranean climate, with a higher seasonal and between-year variation in precipitation than those occurring in the main species distribution (Mosmann *et al.*, Atmospheric Research 70:43–53. 2004). This should favor plastic genotypes, but to properly address phenotypic plasticity, experimental studies with replicated genotypes are needed, *i.e.*, clonal individuals or individuals with known genetic relatedness (Gianoli and Valladares, Biological Journal of the Linnean Society 105:1–7. 2012). In fact, *S. spicant* populations from the Iberian Peninsula have high genetic variation (Peredo *et al.*, American Fern Journal 103:27–39. 2013), which may also explain their phenotypic variation.

Interestingly, we found the majority of small, almost monomorphic individuals (*i.e.*, var. *homophyllum*) on steep slopes with skeletal soils. Water and nutrient availability in this habitat are lower than in forest understories, the typical habitat of var. *spicant*. Thus, this observation is consistent with the positive association between leaf dimorphism and resource-rich habitats (Britton and Watkins, 2016). Because fertile leaves of dimorphic individuals (var. *spicant*) are more upright and longer than sterile leaves, their spores should disperse at greater distances. The fertile pinnae also have a greater proportion of their length covered by cenosori than those of monomorphic individuals, which allows greater spore production in the var. *spicant*. However, under poor growth conditions, these advantages do not compensate for photosynthetic costs, because of reduced lamina area. Common garden or transplant experiments will be required to assess the relative contributions of environmental and genetic factors for the observed phenotype variation.

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Appendix

List of plant material.—(New collections of the varieties *homophyllum* and *pradae* are identified with *; vouchers deposited in the herbarium MA - Real Jardín Botánico de Madrid, Spain).

Struthiopteris spicant var. **homophyllum** (Merino) Gabriel y Galán & R.Pino. Portugal. Azores: San Miguel Island, Algarvia, *L.G. Quintanilla*, 17 Mar 2007, MA 939454*; Trilhos Novos, *L.G. Quintanilla*, 16 Mar 2007, MA 939453*. Braga: Vieira do Minho, *Prada*, 1 Oct 2004, MACB 109621. Madeira Island: ER228 road between Encumeada and S. Vicente, *L.G. Quintanilla*, 02 May 1998, MA 939455*. Spain. A Coruña: A Baña, San Mamede de Monte church, *L.G. Quintanilla*, 13 Aug 2004, MA 939457*; Mariaqueira river, *L.G. Quintanilla*, 21 Feb 2001, MA 939456*; Santiago, Cantaleta, *Barrera*, 29 Jul 1967, MACB 32367. Pontevedra: between Tabagón and Tomiño, *Gabriel y Galán*, 19 Mar 2016, MACB 109617; Mondariz, *Gabriel y Galán*, 20 Mar 2016, MACB 109618. Salamanca: Batuecas, *Gabriel y Galán*, 15 May 2016, MACB 109626. **S. spicant** intermediate between var. **homophyllum** and var. **spicant**. Portugal. Madeira Island: ER228 road between Encumeada and S. Vicente, *L.G. Quintanilla*, 2 May 1998, MACB 113888, MACB 113887, MACB 1138890, MACB 113887. Spain. Canary Islands: Tenerife, Anaga Mountains, *A. Santos,* 25 Oct 1989, MACB 483040. Pontevedra: Mondariz, *Gabriel y Galán*, 20 May 2016, MACB 113881, MACB113883, MACB 113884; Redondela, *I. Barrera,* 1 Nov 1976, MACB 004769. **S. spicant** var. **pradae** S.Molino & Gabriel y Galán. Spain. Asturias: Valdés, Paladeperre, *Gabriel y Galán,* 22 Mar 2016, MACB 109613, MACB 109615; Luarca, *Gabriel y Galán*, 26 Jul 2017, MACB 110660; Otur, *Gabriel y Galán,* 17 Aug 2017, MACB 110661. Burgos: San Millán range, *Fuentes*, 27 Sep 1975, MACB 5994. Zamora: Aciberos, *Molino & al.*, 23 Sep 2017, MACB 110654. León: Hayedo de Busmayor, *R. Vázquez,* 19 Jun 2019, MA 939449*; Pinar de Lillo, *R. Vázquez*, 20 Jun 2019, MA 939450*. Madrid: Rascafría, trail near Pradillo dam, *S. Molino et al.*, 24 Feb 2019, MA 939451*. Navarra: Belagua, towards Lapatia pass, *J.M. Gabriel y Galán & M. Puelles*, 26 Aug 2019, MA 939452*. **S. spicant** intermediate between var. **pradae** and var. **spicant**. Spain. Asturias: Castañedo, *Molino et al.,* 20 Sep 2017, MACB 113877; Otur, *Gabriel y Galán,* 19 Jul 2017, MACB 113876, MACB 113879, MACB 113880. Zamora: Aciberos, *Molino et al.,* 23 Sep 2017, MACB 113878. **S. spicant** var. **spicant**. Belgium. Turnhout: Engels Kamp, *W. van Cotthem*, 18 Jun 1973, MA 809713. Denmark. Faurhult Heat near Frederikshaun, *Lars Jensen et al.,* 26 Jul 1968, MA 213361. France. Autriche, Tyrol, Alpes du Stubai, *D. Podlech*, 18 Aug 1986, MA 464909. Portugal. Azores: S. Miguel Island, Furnas, Terra Nostra Park, *J.A. Ramos & L.G. Quintanilla,* 17 Mar 2007, MACB 113885. Spain. Basque Country: Álava, Ulibarri Olleros, El Portucho, *P.M. Urib-Echevarría,* 10 Oct 1987, MACB 030899. Cantabria: Camaleño, Cosgaya, *Gabriel y Galán*, 1 Oct 2016, MACB 109622. A Coruña: Monfero, Caaveiro, *S. González Crespo,* 18 Oct 1986, MACB 031064. Lugo: Murás, Puente Rioboo, *F.J. Silva Pando et al.,* 2 Aug 1987, MACB 030875.

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Obituary: José María Gabriel y Galán Moris (1968 - 2020)

On March 13, 2020, the eminent and beloved Spanish pteridologist Dr. José María Gabriel y Galán passed away unexpectedly from a heart attack. His loss, at the height of his scientific creativity and productivity, has been a severe blow to Iberian pteridologists and botanists.

José María Gabriel y Galán became a member of the American Fern Society in 2009 and he was an associate editor of the American Fern Journal for nearly a decade. He was born in Madrid, Spain, on May 27, 1968. Although he had many interests, such as astronomy, philosophy, and history, he became attracted to the natural sciences when he discovered the documentaries of Félix Rodríguez de la Fuente, the famous Spanish naturalist, and Sir David Attenborough. Inspired by these two men and with the support of his family, he pursued a bachelor's degree in Biology at Universidad Complutense de Madrid (UCM). Even though being initially more interested in animals, when he started to study botany in his degree it was love at first sight. He became more and more passionate about plants, and finally, in his last year, he ended up choosing the speciality of botany, where he met the woman who became his wife, María Puelles, and with whom he had three children.

He completed his bachelor's degree with a research thesis focused on vegetation and angiosperms, and later he would obtain his PhD with a dissertation on ecology. Following his formal training he held several jobs as a teacher, first in an academy in his village and then as a professor of botany in the degree of Pharmacy at Universidad Alfonso X el Sabio de Madrid (UAX). However, thanks to fate, life brought him back into contact with his old University, where he met Dr. Carmen Prada, who became his mentor and introduced him to the wonderful world of ferns. Since then, José María worked closely with Carmen, starting a fruitful relationship in the teaching of botany and what evolved into an active collaboration in fern research. His interest was focused on systematics, leading him to become part of The Pteridophyte Phylogeny Group (PPG), which, in 2016, published a contemporary revision of the classification system for pteridophytes (PPGI, 2016). At the same time, he also carried out many studies concerning the ecophysiology, biogeography, and development of ferns.

He introduced molecular techniques into the cryptogamic research laboratory, which he invariably combined with the study of plant morphology and anatomy. He was also an active member of the Taxonomic and Diversity research group of the UCM. As a result of his taxonomic studies, he published several combinations and nomenclatural changes: *Lomaridium angustifolium* (Kunth) Vicent & Gabriel y Galán, *Lomariocycas moritziana* (Klotzsch) Gabriel y Galán & Vicent, *Struthiopteris fallax* (Lange) S. Molino, Gabriel y Galán, & Wasowicz, *S. spicant* var. *homophyllum* (Merino) Gabriel y Galán & R. Pino and *S. spicant* var. *pradae* S. Molino & Gabriel y Galán, the latter dedicated to his mentor. As is obvious from these taxa, he was particularly attracted to the family Blechnaceae, although he worked with other groups including members of the Aspleniaceae and Pteridaceae.

In addition to his research work, he was a consistently beloved teacher at the UCM. His students always defined him as demanding but fair, as well as very

funny, always making jokes (sometimes not very good ones) in order to better consolidate student knowledge. As a result, every year he directed bachelor's and master's projects. In addition, in 2017 his student, María Vicent, defended her doctoral dissertation under the supervision of José María and Carmen, which focused on various systematic aspects of the Blechnaceae family. Ultimately, José María supervised three more doctoral theses, one of them (Andrea Seral) considered the ecology of the Aspleniaceae, and two studied systematics of different genera of Blechnaceae, specifically Sonia Molino revised aspects of the genus *Parablechnum* C. Presl and Rubén Vázquez studied *Lomaridium* C. Presl and *Cranfillia* Gasper & V.A.O. Dittrich.

In addition to this research supervision, José María initiated a Fern Identification Course at the Universidad Complutense, which held its fourth iteration last November and which was very well received every year. Moreover, he introduced a cycle of annual seminars in the Botany unit so that all the colleagues could share their lines of research and generate greater unity among the botanists of the UCM.

José María was at all times a strong advocate of herbaria as a source of knowledge, and he became Director of the MACB Herbarium at the Faculty of Biological Sciences of the UCM in 2019.

He was conscious of the value of visiting different environments to enhance his research, thus he travelled extensively to conduct field trips for plant collection and research activities around the world, including Costa Rica, Chile, Brazil, the United States of America, Iceland, and France among others. His passion was so great that he even took advantage of his vacation trips to collect plants with his family and friends. These specimens can still be found in the Fern Laboratory, where they serve as research and teaching aids, especially in the Fern Identification Course.

José María understood science as a field where sharing and teamwork were undoubtedly the best options. With that in mind, he maintained strong collaborations globally with several botanists and pteridologists, and he was always open to bringing new students to his team. He loved his job and clearly transmitted that passion, dedicating much of his time in the University to sharing his knowledge and, with that goal, he created the Fern Laboratory. The Laboratory is now a prolific research group, with two funded research projects and several lines of active investigation. As a mentor he was supportive, confident, and generous, and for those reasons, the team he created will carry on with his legacy and will continue in his steps.

Besides being a great professional, José María was always an example to all the people who crossed his path. He never refused help to anyone, and was always an inspiration for anyone who knew him.

On March 13 of 2020, José María left us early, at the age of 51. His loss leaves a hole in the hearts of those who knew him that can never be filled again. Nevertheless, José María's significant contributions to Pteridology and general Botany will remain forever. Likewise, he leaves behind a solid and consolidated team of young pteridologists who will not hesitate to carry his legacy to the very top, always in his honor. – Sonia Molino, Andrea Seral,

Rubén Vázquez, and Maria Vicent. Department of Biodiversity, Ecology and Evolution, Unity of Botany, Universidad Complutense de Madrid, Avenida Jose Antonio Nováis, 12. 28040 Madrid, Spain.

In memory of
José María Gabriel y Galán (1968-2020)
Eminent pteridologist, dear professor.
From your students, who will always remember you.

Selected Publications of José María Gabriel y Galán (1968-2020)

de la Fuente, P., J. M. Gabriel y Galán, S. Molino, E. Sessa, and L. García Quintanilla. 2020. Character expression, reproductive barriers, and origin of the rare fern hybrid *Asplenium* ×*aran-tohanum* (Aspleniaceae) Plant Systematics and Evolution 306: online http://doi.org/10.1007/s00606-020-01658-8

Gabriel y Galán, J. M., A. Murciano, L. Sirvent, A. Sánchez, and J. E. Watkins. 2018. Germination fitness of two temperate epiphytic ferns shifts under increasing temperatures and forest fragmentation. PLoS ONE 13:e0197110.

Gabriel y Galán, J. M., A. Seral, A. Murciano, R. Anjos, F. B. Cuevas-Fernández, P. Fernández, and T. Pinto. 2018. Ecomorphology of stomata in temperate ferns under contrasting environments. In: Fernández, H. (eds) Current Advances in Fern Research. Springer, Cham.

Gabriel y Galán, J. M. and C. Prada. 2012. Farina Production by gametophytes of *Argyrochosma nivea* (Poir.) Windham (Pteridaceae) and its implications for cheilanthoid phylogeny. American Fern Journal 102:191–197.

Gabriel y Galán, J. M., C. Prada, C. Rolleri, A. Ainouche, and M. Vicent. 2013. cpDNA supports the identification of the major lineages of American *Blechnum* (Blechnaceae, Polypodiopsida) established by morphology. Turkish Journal of Botany 37:769–777.

Gómez-Garay, A., B. Pintos, J. A. Manzanera, C. Prada, L. Martín, and J. M. Gabriel y Galán. 2016. Nanoceria and bulk cerium oxide effects on the germination of *Asplenium adiantum-nigrum* spores. Forest Systems 25:e067.

Migliaro, G. and J. M. Gabriel y Galán. 2012. Gametophyte development and reproduction of the Asian fern *Polystichum polyblepharum* (Roem. ex Kunze) C. Presl (Dryopteridaceae, Polypodiopsida). Plant Biosystems 146:368–373.

Molino, S., J. M. Gabriel y Galán, P. Wasowicz, P. de la Fuente, and E. B. Sessa. 2019. The *Struthiopteris spicant* (Blechnaceae, Polypodiopsida) complex in Western Europe, with proposals for taxonomic and nomenclatural changes. Plant Systematics and Evolution 305:255–268.

Molino, S, J. M. Gabriel y Galán, E. B. Sessa, and P. Wasowicz. 2019. A multi-character review of *Struthiopteris* leads to the rescue of *Spicantopsis* (Blechnaceae, Polypodiopsida). Taxon. 68:185–198.

Molino, S., C. Prada, J. M. Gabriel y Galán, P. Wasowicz, B. Estébanez, and R. Vázquez. 2020. Sporangia and spores in the fern genera *Spicantopsis* and *Struthiopteris* (Blechnaceae, Polypodiopsida). Botanical Review 86:76–92.

Palacios-Rios, M., J. M. Gabriel y Galán, C. Prada, and V. Rico-Gray. 2019. Structure of the petioles and costae of Mesoamerican species of *Pteris* (Polypodiopsida, Pteridaceae). Phytotaxa 401:101–116.

Passarelli, L., J. M. Gabriel y Galán, C. Prada, and C. H. Rolleri. 2010. Spore morphology and ornamentation in the genus *Blechnum* (Blechnaceae, Pteridophyta). Grana 49:243–262.

Prada, C., J. M. Gabriel y Galán, P. Saiz, L. Passarelli, M. Ciciarelli, and C.H. Rolleri. 2016. Caracteres diagnósticos de frondas esporógenas y esporangios de *Blechnum* L. (Blechnaceae). Iheringia Serie Botanica 71:161–174.

Puelles, M., V. Gómez and J. M. Gabriel y Galán (coords.). 2010. Las plantas medicinales de Perú: etnobotánica y viabilidad comercial. Catarata.

Regalado, L., C. Prada, and J. M. Gabriel y Galán. 2010. Sexuality and apogamy in the Cuban *Asplenium auritum-monodon* complex (Aspleniaceae). Plant Systematics and Evolution 289:137–146.

Sessa, E. B., M. Vicent, S. M. Chambers and J. M. Gabriel y Galán. 2018. Evolution and reciprocal origins in Mediterranean ferns: The *Asplenium obovatum* and *A. adiantum-nigrum* complexes. Annals of the Missouri Botanical Garden 103:175–187.

The Pteridophyte Phylogeny Group (Gabriel y Galán, J.M. is member contributor). 2016. A community-derived classification for extant lycophytes and ferns. Journal of Systematics and Evolution 54: 563–603.

Vicent, M., J. M. Gabriel y Galán, and E. Sessa. 2017. Phylogenetics and historical biogeography of *Lomaridium* (Blechnaceae, Polypodiopsida). Taxon 66:1304–1316.

INFORMATION FOR AUTHORS

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